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Tall Fescue:

No-Till Establishment, Defoliation, Growth Distribution, Yield, Stockpiling Management, and Nutritive Value

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Tall Fescue: No-Till Establishment, Defoliation, Growth Distribution, Yield, Stockpiling Management, and Nutritive Value

Contributors

Six independent research studies are reported in this bulletin (for citation purposes and authorship references, refer to the individual studies).

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Front Cover Photos

1. Photo in May of tall fescue growth from a September seeding (left), a March seeding (center), and a February seeding (right). The stands had 15 inches, 1½ inches, and 3 inches of growth, respectively.
2. Defoliation of tall fescue at different frequencies and stubble heights.
3. A cow participates in the selection process of tall fescue strains.
4. Photo on October 1 of tall fescue (left) that had been sprayed with 0.25 pound a.i. paraquat (Gramoxone Extra) on September 15.
5. Tall fescue in late October accumulated from early August.

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.) is a major forage grass grown throughout the north-south transition zone. Much of the research on tall fescue has been conducted at elevations above 500 feet and in the western and northern portions of the transition zone. This bulletin provides information from the eastern portion of the transition zone at an elevation below 500 feet. Specifically, this information covers:

1. the no-till establishment of endophyte-free or novel-endophyte tall fescue into endophyte-infected tall fescue stands that have been killed
2. the influence of various degrees of defoliation on developmental growth, including daily growth rate and associated nutritive value during the growing season
3. the yield potential and nutritive value of late summer-accumulated (stockpiled) tall fescue in the southern and lower elevations (below 450 feet) of the transition zone.

Research findings show that tall fescue pasture yield and quality can be greatly improved through proper defoliation practices and that endophyte-free tall fescue cultivars can be no-till established into infected pastures. Further, the experiments show that with judicious planning and management, producers can effectively use late summer-accumulated tall fescue from October to March. These results have applications wherever tall fescue is grown in North Carolina and in other mid-Atlantic states.

General Summary

Tall fescue introduced into the United States from Great Britain is taller, more drought and cold tolerant, and a denser sod former and, hence, more competitive with weeds than meadow fescue. In the 1800s it was known as Reed fescue (*Festuca elatior* L.), tall meadow fescue, English bluegrass, Randoll grass, and evergreengrass. The initial cultivar releases of Alta from Oregon and Kentucky 31 from Kentucky spurred its use in the United States. Kentucky 31, a cultivar developed from an ecotype found growing in Menifee County, Ky. before 1890, is grown widely throughout the north-south transition zone and comprises a major portion of the acreage in the tall fescue belt today.

Tall fescue is the only long-term (> 4 years) perennial cool-season grass that is well-adapted to the Piedmont region, which extends across the middle south. It is known for its dependability, which is attributed to its adaptation to a wide range of soils and wide fluctuations in summer and winter temperatures and moisture conditions. Further, it is palatable to livestock and affords grazing during most of the year. But animal daily performance is generally moderate to poor during the summer.

A significant practice that merits wider application is the late summer accumulation (stockpiling) of tall fescue for grazing in late fall and into March. Tall fescue has its major growth period in the spring, and the growth terminates with the emergence of seed stalks if left unharvested. The regrowth, however, is essentially all vegetative whether it occurs in summer during periods of cool, moist conditions or in the fall when night time temperatures cool. The stockpile is generally high in soluble sugars and, if topdressed with nitrogen in late summer with the onset of fall growth, is moderate in crude protein concentration.

Poor animal weight gain during the summer in the mid-Atlantic region has been associated with the presence of a fungal endophyte that produces alkaloids. These alkaloids favor tall fescue's persistence but are antagonistic to the animal, causing a condition known as summer syndrome. Studies in this bulletin address the technology needed to establish improved tall fescue cultivars (endophyte-free or with friendly endophyte) into existing tall fescue stands that contain the toxic endophyte. This is particularly important for sites that are not easily tilled for reseeding. Information is also presented on defoliation management during the growing season and on the potential of summer accumulation of tall fescue for fall and winter utilization. The major findings in this bulletin are summarized below.

No-Till Establishment

- Two applications of paraquat (Gramoxone Extra) 1 month apart starting August 15 through October 15 using 0.25 pound active ingredient (a.i.) per acre effectively killed established stands of endophyte-infected tall fescue.
- A single application of 0.50 pound of paraquat a.i. per acre killed established stands but was less effective than two applications of 0.25 pound a.i. per acre applied 1 month apart.
- Tall fescue pastures to be reseeded should not be permitted to produce seed at least 2 years before reseeding.
- For fall no-till seeding into a killed sod, the best time to seed is about October 21 in the piedmont and coastal plain. Earlier dates usually require an approved insecticide to control grasshoppers and crickets.
- Before no-till seeding in February, the old sod should be killed in October or early November.

General Summary

- In 3 of the 4 years evaluated, February seeding generally produced less than half of the dry matter yield obtained from a successful seeding the previous fall.

Defoliation Management of Tall Fescue

- Cutting tall fescue to a stubble of 2 inches every time it reached 6 inches was the most productive defoliation type treatment studied, averaging 8,320 pounds per acre and yielding 33% more total dry matter than the 6-inch treatment cut to a 3.5-inch stubble (6,250 pounds per acre). Seasonal growth rates averaged 22, 23, and 29 pounds per acre per day for years 1, 2, and 3, respectively, of the study.
- Under both the 3.5- and 2-inch stubble systems, more frequent clipping regimes produced marked increases in the leaf area index (LAI) of the stubble.
- Resting tall fescue from June 15 to August 15 generally resulted in increased seasonal dry matter production but ranged from 0 to 15% depending on the treatment. The rest period had little, if any, effect on spring growth the following year.
- Changing the defoliation interval and stubble height favorably shifted forage growth rate and nutritive value during stress periods, which may be of more economic value than producing more seasonal forage.
- Large changes in the daily growth rate (pounds per acre) and nutritive value for each defoliation intensity from year to year emphasize the importance of using variable stocking management for efficient utilization in a livestock production enterprise.

Summer Accumulation for Fall Utilization

- Accumulating tall fescue growth from June 1 resulted in the highest mean dry matter yields by mid-November (4,180 pounds per acre) compared with July 1 (3,320 pounds per acre), August 1. (2,870 pounds per acre), or September 1 (1,480 pounds per acre) accumulation dates. In all cases, 80 pounds of N per acre were applied on August 25. However, the nutritive value of the forage, represented by in vitro dry matter disappearance, was lowest (62%) for the June 1 accumulation and increased to 64% for July 1, 67% for August 1, and 71% for the September 1 accumulation dates. The IVDMD of the June 1-accumulated forage remained lowest during the fall and winter seasons. It ranged from 57% on October 15 to 49% by January 8. This compares with 68 and 56% from the mean of the three later accumulation treatments on the same sampling dates.
- When accumulation began September 1, yields were lowest by mid-November (mean = 1,477 pounds per acre) but nutritive value, represented by IVDMD, was highest when sampled in October (mean = 72%) and remained highest during the fall and winter seasons (ranging from 72 to 60%).
- An August 1 accumulation of tall fescue appears to be a good compromise for producing yield and maintaining nutritive value of accumulated forage as yields were nearly double those from a September 1 accumulation (2,870 vs. 1,480 pounds per acre). But nutritive value, represented by IVDMD, was similar during the fall and winter periods (ranging from 69 to 57%).
- Summer-accumulated forage showed a decline in IVDMD, averaging 8.9 percentage points during December. The nutritive value of the stockpile was associated with the presence of green tissue, which declined in year 2 from a mean of 57 to 26% and in year 3 from a mean of 77 to 24% as the fall-winter season progressed.
- Repeated summer accumulation on the same tall fescue stand had no carryover effects on subsequent spring growth or on subsequent fall accumulations.

Introduction

Tall fescue is the most important cool-season perennial grass in North Carolina, occupying almost 1 million acres. It is a semi-erect bunchgrass that produces short rhizomes, although these rhizomes contribute little to its spread. Tall fescue sometimes is grown in mixture with ladino or red clover, but most of the acreage is seeded in pure stands. Tall fescue is most productive during the spring, with growth declining by early June. Dormancy usually occurs when temperatures exceed 85°F and moisture stress develops in late June through August. A second growth period begins as night temperatures cool in late August and continues into mid-November. The fall growth remains vegetative and can be accumulated for winter grazing, a practice that is not exploited by many livestock producers. Although growth can occur during the winter, it is generally curtailed by temperatures below 45°F (Burns and Chamblee, 1979).

The most widely planted variety of tall fescue in North Carolina and throughout most of the Southeastern United States from the 1950s through much of the 1990s was Kentucky 31. This variety is very persistent and is still widely used in the area.

However, Kentucky 31, Alta tall fescue, and other varieties have been found to be associated with an endophyte fungus, *Neotyphodium coenophialum,* that produces toxic alkaloids. There are three defined fescue toxicoses syndromes in cattle: fescue foot, bovine fat necrosis, and fescue toxicity, also called summer slump. Summer slump is by far the most common syndrome in cattle that graze endophyte-infected tall fescue. This condition is associated with imposed heat tolerance causing a reduction in daily dry matter intake and hence a reduction in daily weight gain. Fescue toxicity also causes serious reproductive problems with pregnant mares. Some specific problems are agalactia (little milk production), abortions, prolonged gestation, and foal deaths. Brood mares should be removed from infected hay or pasture 90 days before foaling.

Endophyte-free varieties have been developed, but they do not appear to be as persistent as the infected ones. In experiments to date in North Carolina, endophyte-free varieties have persisted for 3 to 10 years. Many grazing studies have been conducted in the Southeast. A review of this subject is presented by Fribourg *et al*. (1991). Comparisons of endophyte-infected tall fescue with low-endophyte cultivars have shown daily weight gain advantages for low-endophyte cultivars that range from 0.33 pound in Virginia (Tully *et al*., 1994) to 0.80 pound in Alabama (Hoveland *et al*., 1983). Even larger differences have been obtained in other cases. Differences generally appear to be associated with the length of time grazing is extended into June and July (Burns and Bagley, 1996).

A sampling of over 200 pastures in 80 North Carolina counties indicated that 95% of the pastures were infected with the fungus *Neotyphodium coenophialum*. An average of 68% of the plants in each infected pasture contained the fungus. Toxicity problems from infected tall fescue can be reduced substantially by overseeding pure stands with a legume such as ladino clover. Also, the problem associated with summer slump can be avoided by making other perennial plants available during the summer, such as bermudagrass, switchgrass, flaccidgrass, gamagrass, and dallisgrass or summer annuals such as crabgrass, pearl millet, or sorghum-sudangrass hybrids.

Recently, promise has been shown through a new approach that involves inserting a novel (friendly) endophyte into Georgia 5 and Jesup tall fescue (designated MaxQ). This friendly endophyte is expected to improve stand survival of these cultivars over endophyte-free seed but not depress animal performance as normal endophyte-infected tall fescue does. Because tall fescue is not very productive during midsummer, it should not be relied on as the principal source of feed even when endophyte-free or endophyte-friendly strains are seeded. This bulletin presents results from a number of experiments that address the replacement of endophyte-infected stands with superior fescue cultivars by no-till methods. The experiments also explored spring, summer, and winter management strategies for improving utilization of tall fescue.

No-Till Establishment of Tall Fescue

Study 1. Rate and Date of Paraquat Applications to Kill Existing Sod

Douglas S. Chamblee

Situation

Farmers need a means of shifting from infected tall fescue to either endophyte-free varieties or improved varieties infected with a friendly endophyte using no-till methods. First, the old sod must be killed, and then the insects present in the old sod must be controlled. Consequently, the objective of this study was to determine the best method of killing infected tall fescue stands without tillage to permit the seeding of a different tall fescue.

Experimental Procedures

Four identical experiments were conducted over 4 years at the Lake Wheeler Road Field Laboratory on an Appling clay loam (Experiments 1, 2, and 4) and at the Reedy Creek Road Field Laboratory on a Cecil clay loam (Experiment 3) near Raleigh, N.C. Soil pH for all sites ranged from 6.0 to 6.3 and no additional limestone was added. Both P_2O_5 and K_2O were applied in the year of grass kill according to soil test requirements for tall fescue. All plots received 50 pounds of nitrogen in February and again August 1 before the spray treatments were applied.

The experiments compared different rates and dates of applying paraquat (Gramoxone Extra) onto a sod of established (2 to 4 years) Kentucky 31 tall fescue (see Table 1.1 for variables). The existing sod was grazed or mowed (with the clippings removed) to a stubble height of about 2 inches at 2 weeks and again at 3 days before paraquat was applied. Plots were 7 feet by 15 feet with 8-foot alleys. The various treatments were arranged in a randomized complete block design with four replications. Paraquat was broadcast sprayed using 20 gallons of water per acre with a CO_2-pressurized backpack sprayer on the dates indicated in Table 1.1.

In order to better evaluate the effectiveness of the spray, nothing was seeded into the sprayed sod. Two observers checked the stands periodically during the fall and following spring and reported their results as percentage ground cover of green tall fescue. Weed encroachment was checked and also recorded but not reported.

Results and Discussion

Date and Rate Effects

Two applications of paraquat at 0.25 pound a.i. per acre 1 month apart (August 15 and September 15, September 15 and October 15, or October 15 and November 15) proved effective in killing an existing sward of infected Kentucky 31 tall fescue. The maximum amount of ground cover of tall fescue remaining on May 31, the spring following these double applications, was 8.2% (Table 1.1, Experiment 3). In the majority of the experiments, 1% or less of the fescue survived double applications at 0.25 pound a.i. per acre in late summer and fall.

June and July applications were not nearly as effective as those made in late summer and fall. A doubling of the rate from 0.25 to 0.50 pound a.i. per acre proved advantageous in several comparisons. For example, an application of 0.50 pound a.i. per acre September 15 resulted in a green tall fescue ground cover range of 0 to 9.5% compared with 4.7 to 23.7% for the 0.25 rate. These sites were carefully selected. The Kentucky 31 tall fescue sods were not permitted to make seed for at least 2 years before the trials began. This was to avoid any volunteer reseeding. Also, the sods were closely defoliated (back to 2 inches) for some weeks before paraquat was sprayed.

Table 1.1. Effect of rate and date of paraquat applications on the kill of established Kentucky 31 tall fescue.

Treatment[a]			Ground cover green tall fescue								
			Exp. 1		Exp. 2		Exp. 3			Exp. 4	
No.	Rate	Date	9 Dec.	May 28	Nov. 21	Mar. 21	Oct. 21	Jan. 30	May 31	Feb. 16	April 4
	lb a.i./acre		%								
1)	0.25	June 10	8.7[b]	15.7	13.7	10.5	38.7	25.2	45.0	30.0	45.0
2)	0.25	June 10 & July 10	2.5	3.5	4.2	3.0	8.7	6.5	11.5	8.5	17.0
3)	0.25	June 10, July 10, & Sept. 10	1.2	0.8	1.5	0.0	0.0	0.2	1.2	—[c]	—
4)	0.50	June 10	2.0	5.7	9.2	10.7	11.0	8.2	21.7	23.7	37.5
5)	0.25	Aug. 15	0.7	0.3	11.2	9.7	23.7	22.7	38.7	2.2	6.0
6)	0.25	Aug. 15 & Sept. 15	0.0	0.0	1.0	0.0	0.5	4.0	1.0	0.0	1.0
7)	0.50	Aug. 15	0.2	0.3	5.5	2.0	8.0	11.7	20.5	0.2	2.0
8)	0.25	Sept. 15	4.7	6.7	10.2	6.5	18.5	12.7	23.7	8.2	15.2
9)	0.25	Sept. 15 & Oct. 15	0.0	0.0	1.0	0.3	3.5	0.0	1.0	0.0	0.0
10)	0.50	Sept. 15	1.2	1.3	3.5	2.7	6.2	5.0	9.5	0.0	2.5
11)	0.25	Oct. 15	13.7	17.0	22.5	23.7	0.0	1.2	15.0	1.2	10.2
12)	0.25	Oct. 15 & Nov. 15	0.0	0.0	—	—	0.0	0.0	8.2	0.0	0.2
13)	0.50	Oct. 15	4.2	3.5	5.0	0.2	0.0	0.0	10.0	0.0	2.0
14)	Check		85.0	62.0	83.7	82.5	85.5	78.2	82.5	71.2	82.5
LSD (0.05)[d]			1.5	2.2	3.5	2.9	4.3	3.1	4.6	2.8	4.1

[a] Either 0.25 or 0.50 pound active ingredient (a.i.) per acre of paraquat (Gramoxone Extra) was applied to fescue at indicated dates. In experiment 4, treatments 1, 2, and 4 were applied 1 month later. For example, treatment 1 became 0.25 July 10.
[b] Each value is the mean of four replicates.
[c] — indicates that measurements were not taken.
[d] LSD = least significant difference.

Weeds

Plots of tall fescue receiving paraquat in June or July quickly became heavily infested. At least 40% of the ground was covered with weeds such as leafy spurge, *Paspalum* species, horsenettle, crabgrass, green foxtail, and cow itch vine. Those stands sprayed in the fall also had some moderate invasion of henbit and chickweed. If those plots had been seeded to tall fescue, this invasion would have been much less. For reasons previously explained, fescue was not seeded.

Summary and Conclusions

- Established stands of endophyte-infected tall fescue can be effectively killed with two applications of paraquat (Gramoxone Extra) 1 month apart either on August 15 and September 15, September 15 and October 15, or October 15 and November 15 using 0.25 pound a.i. per acre.
- Single applications of 0.50 pound a.i. per acre of paraquat are more effective than single rates of 0.25 pound a.i. per acre but less effective than two applications of 0.25 1 month apart.
- For February seedings of tall fescue, the old sod of fescue first should be killed in October or early November.
- Infected tall fescue pastures should not be permitted to produce seed for at least 2 or 3 years before no-till seeding of noninfected varieties.

Study 2. Date of Seeding With and Without an Insecticide

Douglas S. Chamblee

Situation

Producers who use no-till methods to shift from infected tall fescue stands to stands of either endophyte-free varieties or improved varieties infected with a friendly endophyte frequently encounter insect pests at the seeding dates previously considered optimum. The objective of this study was to determine the best time to establish endophyte-free tall fescue varieties into the killed sod with and without an insecticide—as well as the best method for doing so.

Experimental Procedures

Four identical experiments were conducted over 4 years at the Reedy Creek Road Field Laboratory on a Cecil clay loam (Experiments 1 and 2) and at the Lake Wheeler Road Field Laboratory on an Appling clay loam (Experiments 3 and 4) near Raleigh, N.C. Soil pH for all sites varied from 6.1 to 6.3 and no additional limestone was added. Both P_2O_5 and K_2O were applied to the established tall fescue stand in the spring before new stands of fescue were seeded and again the following spring according to soil test requirements. Nitrogen applications are discussed below.

The experimental variables were arranged in a randomized complete block design with four replicates. The experiments compared different dates of seeding an endophyte-free variety of tall fescue, Forager, into a killed sod of a well-established stand (2 to 4 years old) of endophyte-infected Kentucky 31 tall fescue (see Table 2.1 for dates). Forager was drill seeded into the killed sod with and without applications of the insecticide carbofuran (in granular form) at 1.5 pounds a.i. per acre. Paraquat (Gramoxone Extra) was broadcast sprayed at 0.25 pound a.i. per acre 1 month before fall seedings and again 1 day before seeding. The Kentucky 31 fescue sod had been cut back repeatedly to 2 inches 1 month before seeding. For winter seedings, the paraquat was applied October 1 and November 1 at the same rates. Previous studies have shown that applications during December, January, and February are not effective.

For the fall and winter seedings (see Table 2.1), nitrogen was applied at 50 pounds per acre at the time of seeding. An additional 50 pounds of nitrogen were applied on February 15 on the fall seedings and April 15 on the winter seedings. Forager was drill seeded at 16 pounds per acre into eight rows per plot spaced 10 inches apart using a Tye Pasture Pleaser no-till drill. The plots were 7 feet by 20 feet with a 20-foot alley. The drill was adjusted to make a furrow about 0.75 inch deep, which resulted in the seed being covered with about 0.5 inch of soil.

Table 2.1. Effect of date of seeding and use of the insecticide carbofuran (C) on stand establishment of endophyte-free tall fescue seeded into a sod of killed endophyte-infected tall fescue.

Treatments[a]						
No.	Date	C	Exp. 1	Exp. 2	Exp. 3	Exp. 4
			.... plants per square foot[b]			
1)	Sept. 1	C	10[c]	20	—[d]	29
2)		No C	4	7	—	18
3)	Oct. 1	C	21	4	10	13
4)		No C	9	0.6	11	10
5)	Oct. 21	C	21	8	24	18
6)		No C	18	5	23	15
7)	Feb. 15	C	16	23	27	29
8)		No C	19	25	26	28
9)	Mar. 15	C	30	25	25	22
10)		No C	27	22	19	20
LSD[e] (0.05)		5.2	3.1	3.5	4.4	

[a] Sept. 1 C denotes that tall fescue was no-till drilled into a killed sod of tall fescue on September 1 and that 1.5 pounds a.i. per acre of granular carbofuran were drilled simultaneously into the rows.
[b] Stand counts were made about 3 weeks after seeding in the fall and 4 to 6 weeks after seeding in the winter.
[c] Each value is the mean of four replicates.
[d] Unable to penetrate the soil with a no-till drill on this date due to drought conditions. Complete stand failure occurred in treatments 1 and 2, Experiment 3.
[e] LSD = least significant difference.

Stands were evaluated by counting 12 areas, 10 inches by 12 inches, using a portable frame to outline the area in each plot. These counts were made about 3 weeks after seeding in the fall and 4 to 6 weeks after seeding in the winter. Ground cover of seeded tall fescue and canopy height were measured periodically.

Dry matter yield estimates were obtained at some harvests from a strip 30 inches wide cut from the center of the plot to a 2-inch stubble and dried at 135°F for 48 hours. In two experiments at two dates in the fall, insect damage and leaf necrosis damage were determined by examining plants from six areas, each 6 inches long, from each plot taken outside the harvest strip.

Results and Discussion

Stands

Good stands of tall fescue were consistently obtained in February and March, and in most years from an October 1 no-till seeding. But September 1 seedings produced erratic stands. Insects and drought contributed to the erratic fall stands. The use of carbofuran was effective in producing better stands at most September 1 and October 1 seedings, but showed little effect at the October 21 date due to less insect pressure. The data show that without an insecticide the October 21 date offers less risk of insect or drought damage than the earlier fall dates (Table 2.1). Previous studies in North Carolina on no-till procedures for fall establishment of ladino clover into partially killed fescue swards showed that insects were a great hazard to successful September seedings but exhibited much less damage to stands seeded in mid-October (Rogers *et al*., 1983).

Yields

Dry matter yield determinations were not usually made throughout the growing season (Table 2.2). For example, in Experiment 2 only one harvest was made the first year on April 25, and in Experiment 3, one harvest was made in the first year on June 21. These data showed that much higher spring yields were obtained from successful fall seedings than from winter seedings. For example, in Experiment 4, by April 22, 3,640 pounds per acre of dry matter were harvested from plots seeded with insecticide on September 1, whereas the stands seeded on February 15 and March 15 had not made enough growth for harvest.

In all trials over the 4 years, there was sufficient moisture for stand survival of winter seedings, but yields in the first growing season were usually much less than from successful fall seedings. No yield response to carbofuran was obtained at the winter

Table 2.2. Effect of date of seeding and use of the insecticide carbofuran (C) on dry matter yield of an endophyte-free tall fescue seeded into a sod of killed endophyte-infected tall fescue.[a]

Treatments[b]			Exp. 1		Exp. 2		Exp. 3	Exp. 4	
			1st yr	2nd yr	1st yr	2nd yr	1st yr	1st yr	
No.	Date	C		March 22	April 25	March 22	June 21	April 22	Aug. 9[c]
			pounds per acre						
1)	Sept. 1	C	4,640[d]	1,620	2,540	940	—[e]	3,640	1,600
2)		No C	3,540	1,250	2,140	1,060	—	3,260	2,220
3)	Oct. 1	C	4,270	1,460	140	380	1,820	2,560	2,620
4)		No C	3,520	1,560	40	250	1,050	1,760	3,120
5)	Oct. 21	C	4,400	1,250	170	590	1,910	1,930	2,790
6)		No C	3,240	1,370	160	450	2,280	1,180	3,180
7)	Feb. 15	C	3,740	1,550	0[f]	560	870	0	2,200
8)		No C	3,360	1,590	0	440	680	0	1,960
9)	Mar. 15	C	3,870	1,510	0	490	980	0	2,010
10)		No C	3,960	1,520	0	500	860	0	1,690
LSD[g] (0.05)			740	340	200	320	330	760	620

[a] Experiments were not harvested regularly throughout the growing season. Experiment 1 yields in the first year are totals from two harvests taken April 18 and June 28.

[b] Sept. 1 C denotes that tall fescue was no-till drilled into a killed sod of tall fescue on September 1 and that 1.5 pounds active ingredient (a.i.) per acre granular carbofuran were drilled simultaneously into the rows.

[c] These data are presented weed-free; however at this August 9 harvest, Experiment 4, crabgrass (weight not included) constituted about 8 and 51% of the total yields for treatments 1 to 6 and 7 to 10, respectively.

[d] Each value is the mean of four replicates.

[e] Unable to penetrate the soil with a no-till drill on this date due to drought conditions.

[f] "0" denotes insufficient growth to harvest these treatments.

[g] LSD = least significant difference.

Table 2.3. Effect of date of seeding and use of the insecticide carbofuran (C) on height (Ht) and ground cover (GC) of an endophyte-free tall fescue seeded into a sod of killed endophyte-infected tall fescue.

Treatments[a]			Exp. 1	Exp. 2		Exp. 3		Exp. 4	
			GC[b]	Ht	GC	GC		Ht	GC
No.	Date	C	June 18	Apr. 21	Sept. 11	June 21	Apr. 18	June 10	
			%	in.	%	%		in.	%
1)	Sept. 1	C	82[c]	15	92	86	—[d]	15	91
2)		No C	44	14	65	64	—	14	76
3)	Oct. 1	C	82	6	30	35	89	13	78
4)		No C	42	6	8	15	81	10	55
5)	Oct. 21	C	80	7	47	50	92	10	81
6)		No C	70	7	39	40	91	10	72
7)	Feb. 15	C	72	2	91	80	85	3	91
8)		No C	71	2	91	82	90	3	90
9)	Mar. 15	C	76	1.5	93	85	91	2	90
10)		No C	71	1.5	92	84	92	2	76
LSD[e] (0.05)			8.8	2.1	21	24	13	2.2	7.4

[a] Sept. 1 C denotes that tall fescue was no-till drilled into a killed sod of tall fescue on September 1 and that 1.5 pounds active ingredient (a.i.) per acre granular carbofuran were drilled simultaneously into the rows.
[b] Denotes ground cover of green tall fescue within the row.
[c] Each value is the mean of four replicates.
[d] Unable to penetrate the soil with a no-till drill on this date due to drought conditions.
[e] LSD = least significant difference.

seeding dates of February 15 and March 15, whereas some marked responses were noted in the fall.

Ground Cover and Height

The tall fescue ground cover was better from many of the treatments receiving carbofuran (C) in the fall, particularly the September 1 and October 1 seedings (Table 2.3). For example, in Experiment 2 the ground cover of fescue for September 1, C and No C, was 92 and 65%, respectively, and for October 1 was 30 and 8%, respectively. No effect of C on ground cover was noted in the winter seedings. The height measurements (Table 2.3) showed the superiority of successful fall seedings over winter seedings. Fescue seeded the previous September 1 was about 15 inches high in April (Experiment 2) and June (Experiment 4) compared with 1.5 to 3 inches for the winter-seeded stands.

Insect Damage and Leaf Necrosis

Carbofuran was effective in controlling insects and in reducing leaf necrosis damage (Table 2.4). In

Table 2.4. Effect of date of seeding and use of the insecticide carbofuran (C) on insect damage and leaf necrosis of an endophyte-free tall fescue seeded into a sod of killed endophyte-infected tall fescue.

Treatments[a]			Exp. 1		Exp. 2	
No.	Date	C	Insect[b] damage	Leaf[c] necrosis	Insect damage	Leaf necrosis
			%			
3)	Oct. 1	C	9[d]	12	—[e]	—
4)		No C	6	24	—	—
5)	Oct. 21	C	9	23	16	19
6)		No C	9	43	32	27

[a] Oct. 1 C denotes that tall fescue was no-till drilled into a killed sod of tall fescue on October 1 and that 1.5 pounds active ingredient (a.i.) per acre granular carbofuran were drilled simultaneously into the rows.
[b] Denotes leaves with obvious insect damage (biting or chewing).
[c] Denotes leaves exhibiting necrosis.
[d] Each value is the mean of four replicates.
[e] No measurements were taken.

Experiment 1, approximately twice as many plants exhibited leaf necrosis in the untreated plots compared with the treated plots.

Summary and Conclusion

- The best time for no-till establishment of endophyte-free tall fescue, or perhaps one of the improved cultivars with a friendly endophyte, into a killed sod of endophyte-infected tall fescue without the use of an insecticide is about October 21 in the piedmont and coastal plain of North Carolina. Earlier dates in October or September would be successful with the use of an approved insecticide. Although carbofuran is presently not approved for use on stand establishment of forages, other registered products should be considered. Grasshoppers and crickets seem to cause the most damage.
- Successful stands of tall fescue may be obtained in February and March, but the first year's production of forage was much lower in 3 of the 4 years evaluated, averaging less than half of that from a successful fall seeding. Also, there is more risk of losing winter-seeded stands to summer drought. In this 4-year study, summer moisture was sufficient to avoid summer stand losses frequently encountered from winter seedings.

Defoliation Management of Tall Fescue

Study 3. Influence of Defoliation Frequencies on the Morphological Development and Growth of Tall Fescue

Douglas S. Chamblee and Charles H. Isley

Situation

Matches (1979) has reviewed the pertinent literature relating to frequency of defoliation, height of cutting, and other aspects of management. Sleper and Buckner (1995) have presented some pertinent results on grazing management of tall fescue, and Juska *et al*. (1969) noted that tall fescue cut to 1 and 2 inches showed greater tillering than when cut to 3 inches. Sleper and Nelson (1989) noted that tillering of tall fescue is stimulated by frequent defoliation. Burns (1970) found that approximately 65% of the dry matter was present below the 2-inch level in frequent harvests of tall fescue. The objectives of this study were to:

a. determine the effects of different defoliation intensities on leaf area indices, nitrogen concentration, and overall growth of tall fescue and
b. devise management systems that would result in a maximum rate of regrowth.

Experimental Procedures

This study was conducted over 3 years (plus one uniform harvest in the fourth year) on a Cecil clay loam at the Reedy Creek Field Laboratory near Raleigh, N.C. Sixteen treatments were arranged in a randomized complete block design with four replications. Each plot was 6 feet wide by 20 feet long with a 5-foot alley between replicates.

The experiment was seeded to Kentucky 31 tall fescue in September, and the various defoliation treatments, as listed in Table 3.1, were initiated the following spring. The tall fescue in one-half of the plots was cut periodically throughout the growing season; the other half was given a rest period from June 15 to August 15. When forage in the plots given a summer rest period reached 10 to 12 inches, it was cut back uniformly to 3.5 inches. In the first and third years, no harvests were made during the summer rest period due to insufficient growth. Two harvests were made of all summer rest plots in the second year. Individual harvest data are not reported

Table 3.1. Defoliation treatments imposed on tall fescue.

Management[a]	Treatments
A. Cut all season	(1) Cut when 3 inches back to 1.5 inches (3-1.5)
	(2) Cut when 3 inches back to 2 inches (3-2)
	(3) Cut when 4 inches back to 2 inches (4-2)
	(4) Cut when 6 inches back to 2 inches (6-2)
	(5) Cut when 12 inches back to 2 inches (12-2)
	(6) Cut when 4.5 inches back to 3.5 inches (4.5-3.5)
	(7) Cut when 6 inches back to 3.5 inches (6-3.5)
	(8) Cut when 12 inches back to 3.5 inches (12-3.5)
B. Summer rest[b]	(rested between June 15-August 15)
The same cutting treatments outlined under A (1-8) were imposed in management B, except during June 15 to August 15, when the eight treatments were cut back to 3.5 inches only when growth reached 10 to 12 inches.	

[a] For example, cut when 3 inches back to 1.5 inches (3-1.5) denotes that tall fescue was cut back to a stubble height of 1.5 inches each time growth reached 3 inches.
[b] Growth made during the summer rest period was harvested at the end of each rest period and is included in total growth for the season.

in this manuscript; however, as an example, the "cut all season" treatment that involved cutting from 3 inches to 2 inches included seven cuts between June 15 and August 15 in the second year. The same treatment on the "summer rest period" plots involved two cuts.

Fertilization at seeding included 22 pounds N, 132 pounds P_2O_5, 132 pounds K_2O, and 2 tons dolomitic limestone per acre. A topdressing of 32 pounds N per acre was applied in October. Annually, 240 pounds N, 72 pounds P_2O_5, and 216 pounds K_2O per acre were applied. The N was applied February 15, April 15, and September 15 at 100, 60, and 80 pounds per acre, respectively. The P_2O_5 and K_2O were applied February 15. These materials were applied within a week of the above dates.

Harvesting for yield was initiated in March of the first year. With the exception of the 12-inch- to 2-inch and 12-inch to 3.5-inch treatments, the plots were cut with a rotary-type mower equipped with a detachable bag. The 12-inch to 2-inch and 12-inch to 3.5-inch treatments involved cutting with a 24-inch cutter-bar-type mower, and the samples were raked and placed in cloth bags. An area 24 inches wide by 18 feet long was harvested from the center of each plot for yield determination, and the sample was dried in a forced air dryer and permitted to air equilibrate to about 15% moisture. At each harvest date a strip approximately 12 inches wide was harvested from each end of the plots and discarded. After sampling, the borders were cut in a manner similar to the harvest strip and the vegetation was removed from the plots. During the first year of establishment, force created by the rotary-type mower blew soil particles into the sample bag along with the grass clippings when clipping the 3-inch to 1.5-inch treatments. The soil particles were separated from the grass with a sieve that had small-diameter openings. Once the tall fescue had formed a dense sod, sieving was not required.

Nitrogen concentration of the forage was determined plot by plot according to the AOAC (1990) method of analysis. Samples were taken each spring and in the fall of the first and second years. Because the cutting schedule for treatments varied, forage from treatments sampled for nitrogen were not cut on the same day but within a 6-day period.

In the third year, samples of fresh forage were separated by hand into four fractions. These were green blades, stems with sheaths, dead blades, and duff. The green blades and dead blades were removed at the collar, but the sheaths remained with the stems. The duff material consisted of weeds, soil, organic material, and other extraneous matter. The duff was discarded. Samples used for botanical separations and leaf determination were collected randomly within the plots but outside the harvest strip utilized for yield. Two samples, one from the north position and one from the south position (the long axis of plots was oriented north and south) were taken before and after harvesting for yield. The samples used for botanical separations and leaf area determination were harvested to soil level from an area 6 inches wide by 24 inches long. Sampling was done in the spring and fall of the second year. Due to treatment variables, it was not possible to harvest all the samples for botanical separations on the same day; the harvests were made over a period of 10 to 14 days at each sampling period.

All materials from the harvested area were placed in plastic bags immediately, placed in a Styrofoam cooler containing ice to prevent wilting, and stored in a room at 40°F. Past experience had shown that separations and measurements, particularly for leaf area index (LAI), could best be made in an air-conditioned room. At ordinary room temperature, the blades rolled, making measurements of LAI impossible. Subsamples, consisting of approximately 30 grams of "total height" material and 25 grams of "stubble height" material, were separated into green blades, stems with sheaths, dead blades, and duff. The remainder of the subsample was used for leaf area determination. All components were placed in paper bags and dried in a forced-air oven at 150°F for 24 hours. After drying, the samples were removed and stored at room temperature until weighed.

Fifty green blades taken at random from the remainder of the sample were used for LAI determinations. The drying, storing, and weighing procedures were the same as for botanical analysis.

A combined analysis over years as well as for the individual sampling periods was performed on the percentages of green blades, stems with sheaths, dead blades, and leaf area index. A combined analysis was conducted on total yields. Individual analyses were made for each nitrogen determination. Differences showing significance at the 0.05 level will be noted as differences unless otherwise indicated.

Results and Discussion

Total Dry Matter Production

In this study, stands that were harvested at a height of 6 inches or less will be referred to as "grazing-type," and those permitted to reach a height of 12 inches will be referred to as "hay-type." Most produced more total dry matter in the second year than in the first or third (Table 3.2). A severe summer drought in the third year decreased yield. The monthly precipitation from June through September in the third year was 1.7, 4.0, 1.35, and 1.10 inches, respectively, compared with the long-term normals of 4.22, 5.44, 5.32, and 3.70 inches.

Table 3.2. Total dry matter produced by tall fescue as influenced by height and frequency of defoliation.

Treatments[a]	Year			Avg.
	1st	2nd	3rd	
inches	.... lb/acre			....
Cut all season				
3-1.5	6,430[b]	7,660	7,020	7,040
3-2	7,100	8,370	7,400	7,620
4-2	6,860	8,640	7,600	7,700
6-2	7,280	9,180	8,500	8,320
12-2	8,510	10,570	8,910	9,330
4.5-3.5	6,780	6,150	5,840	6,260
6-3.5	6,890	6,150	5,700	6,250
12-3.5	8,880	9,120	8,050	8,690
Summer rest period[c]				
3-1.5	7,980	9,040	7,270	8,100
3-2	8,390	8,620	7,290	8,100
4-2	7,990	8,990	7,210	8,060
6-2	8,870	9,150	8,820	8,940
12-2	9,820	10,980	8,740	9,850
4.5-3.5	7,700	7,270	6,130	7,030
6-3.5	7,750	6,710	5,640	6,700
12-3.5	8,760	8,930	8,170	8,620
LSD[d] (0.05)	280	280	280	270

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches.
[b] Each value is the mean of four replicates.
[c] See Table 3.1.
[d] LSD = least significant difference.

When averaged for the experiment, all summer rest treatments, except the 12-inch to 3.5-inch treatment, produced an average of more total dry matter than treatments harvested all season. The largest increase in total dry matter production for the 2-month summer rest period was 15%, which was obtained from the 3-inch to 1.5-inch treatment. Although the "hay-type" treatments produced more total dry matter than the "grazing-type" treatments, it is generally more economical to graze tall fescue than to harvest it three to four times a year as hay.

In comparing the "grazing-type" treatments (< 6 inches), marked increases were noted in total dry matter production when tall fescue was defoliated back to a 2-inch stubble as compared with a 3.5- and 1.5-inch stubble (Table 3.2). For example, when cut all season, the 6-inch to 2-inch treatment yielded 2,070 more pounds per acre annually than the 6-inch to 3.5-inch treatment. Further, the 6-inch to 2-inch treatment produced about 2,060 pounds per acre more than the 4.5- inch to 3.5-inch treatment. The least desirable stubble height for production was 3.5 inches.

On the average, the 6-inch to 2-inch treatment proved to be the most productive "grazing" management intensity in this study. The most severely defoliated treatment, 3-inch to1.5-inch, yielded less than those "grazing-type" treatments that were harvested all season back to 2 inches. But when a summer rest period was imposed, the 3-inch to 1.5-inch treatment produced as much or more total forage as any of the "grazing-type" treatments with the exception of the 6-inch to 2-inch treatment (Table 3.2). Hart *et al*. (1971) have shown that tall fescue cut weekly after flowering to heights of 2, 4, or 8 inches produced more yield in the second and third years at the lower stubble height. Their studies did not include defoliation before flowering. In North Carolina the period before flowering is the period of greatest seasonal growth. Others (Dobson *et al*., 1975; 1978) also report more forage production may be obtained at the lower grazing heights,

Table 3.3. Dry matter produced by tall fescue in late summer and fall as influenced by a summer rest period under various heights and frequencies of defoliation.

	Yield after Aug. 24 2nd year		Yield after Aug. 29 3rd year	
Treatments[a]	Cut all season	Summer rest period	Cut all season	Summer rest period
inches	.... lb/acre			
3-1.5	1,380[b]	1,350	1,550	1,500
3-2	1,660	1,820	1,330	1,380
4.5-3.5	1,350	1,160	910	990
6-3.5	1,110	910	930	940
12-3.5	1,410	1,490	1,290	900

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches.

[b] Each value is the mean of four replicates. Least significant difference (0.05) between "cut all season" and "summer rest period" for the above comparisons was not significant.

and Burns and Goode (1972) obtained excellent animal performance by overseeing grazing to stubble heights of 2 to 3 inches. As expected, the greatest total dry matter production in this study was obtained from the 12-inch "hay" treatments. Considering both management strategies, the 12-inch to 2-inch treatment produced 935 pounds per acre more dry matter per year over 3 years than the 12-inch to 3.5-inch treatment.

Seasonal Dry Matter Production

The effect of summer rest on fall and spring growth of tall fescue is illustrated in Tables 3.3 and 3.4. At the first harvest in the spring, the "cut all season" and the "summer rest period" were cut at the same time for any given height of cut treatment such as 6 inches to 3.5 inches. Consequently, one can determine the effect of summer rest on spring vigor by examining the data from the first harvest (Table 3.4). Data from individual harvests in fall and spring showed essentially no difference between samples collected from rested and nonrested treatments either in the fall or the following spring after the summer rest growth had been removed (Tables 3.3 and 3.4). The yield advantages obtained from the summer rest treatments were largely realized during the rest period itself or immediately thereafter. During 1 summer of high rainfall (second year), tall fescue showed more disease prevalence in plots subjected to a rest period. The reaction of tall fescue to summer defoliation in North Carolina in this trial differed from the reaction found in Alabama. Berry and Hoveland (1969) reported that summer resting of tall fescue appeared necessary for maximum fall-winter production in the lower southeastern United States.

Table 3.4. Dry matter production of tall fescue at the first spring harvest as influenced by a summer rest period under various heights and frequencies of defoliation.

	Spring 2nd year		Spring 3rd year		Spring 4th year	
Treatments[a]	Cut all season	Summer rest period	Cut all season	Summer rest period	Cut all season	Summer rest period
inches	.... lb/acre					
3-1.5	700[b]	750	800	780	340	350
3-2	460	430	790	680	340	360
4-2	1,350	1,180	600	520	450	410
12-2	2,880	2,930	3,770	4,060	1,870	1,940
4.5-3.5	210	210	620	560	240	260
6-3.5	730	620	1,260	1,150	290	270
12-3.5	2,270	2,260	3,770	3,880	1,860	1,980

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches. The first spring harvest for each cutting height treatment was cut according to the prescribed treatment, and consequently, occurred at different dates; for example, in the second year the first spring harvest for the 4.5-inch to 3.5-inch treatment was made on March 24 compared with April 25 for the 12-inch to 3.5-inch treatment. For any cutting height, for example 4 inches to 2 inches, the "cut all season" and "summer rest period" treatments were cut at the same time for the first harvest.

[b] Each value is the mean of four replicates. Least significant difference (0.05) between "cut all season" and "summer rest period" for the above comparisons was not significant.

They concluded that summer defoliation may stimulate tiller growth and deplete plant carbohydrate reserves needed for fall growth.

The yield data for all of the individual harvests are not reported; however, an examination of these data showed that, in general, tall fescue responded similarly to defoliation before and after June 15. Some differences in magnitude were noted between treatments before and after June 15, but these differences were not large. On the average, more dry matter was produced before June 15 than after June 15. Seasonal production of dry matter varied considerably among years. For example, the production for the "grazing-type" treatments before June 15 averaged approximately 60, 40, and 70% for the first, second, and third years, respectively. Fescue usually grows more rapidly in the spring, producing more dry matter at that time than in the fall.

Nitrogen Percentage

The more frequently defoliated treatments resulted in a higher nitrogen percentage in the tall fescue than the treatments permitted to reach 12 inches (Table 3.5).

Table 3.5. Average percentage of nitrogen in stems and leaves of tall fescue from spring and fall harvests for the second and third years.

	Spring		Fall	
Treatments[a]	Cut all season	Summer rest period	Cut all season	Summer rest period
inches	%			
3-1.5	3.11[b]	3.30	3.90	3.93
3-2	3.15	3.75	3.89	3.85
4-2	3.16	3.36	3.82	3.86
6-2	3.02	3.25	3.12	3.14
12-2	2.56	2.67	2.24	2.43
4.5-3.5	3.39	3.40	3.71	3.66
6-3.5	3.24	3.34	3.54	3.52
12-3.5	2.83	2.90	2.57	2.61
LSD[c] (0.05)	0.14	0.14	0.14	0.14

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches.

[b] Each value is the mean of four replicates.

[c] LSD = least significant difference.

The "grazing-type" defoliation treatments that involved cutting all season produced nitrogen readings ranging from 3.02 to 3.39% in the spring and from 3.12 to 3.90% in the fall. The 3-inch to 2-inch defoliation treatments produced a forage that had a greater nitrogen percentage than the 6-inch to 2-inch system (average summer and fall). In general, the percentage of nitrogen in stems and leaves was not greatly different in fall or spring.

The forage from the 6-inch to 2-inch treatment contained a slightly lower percentage of crude protein (nitrogen x 6.25) than the forage from the 6-inch to 3.5-inch treatment (Table 3.5). The "grazing-type" treatments (cut all season) produced, on the average, from 19.2% crude protein (6-inch to 2-inch treatment) to 22.2% crude protein (4.5-inch to 3.5-inch treatment).

Leaf Area Index

The highest leaf area index (LAI) of the total plant of tall fescue was obtained from the least severe treatments (12 inches to 3.5 inches and 12 inches to 2 inches) (Table 3.6). On the average, there was no difference among the remaining treatments as the severity of defoliation was increased. An exception was the 3-inch to 1.5-inch treatment, which had the lowest LAI (3.7). Increasing the severity of defoliation by cutting from 3 inches to 1.5 inches decreased the LAI by 56.5% compared with the least severe defoliated treatment, 12 inches to 3.5 inches (Table 3.6).

Brougham (1958) found the following leaf area indices at which 95% of the incident light was intercepted about midday in summer: perennial ryegrass 7.1, short rotation ryegrass 7.1, white clover 3.5, and a mixed stand 4.5. Tall fescue is similar morphologically to ryegrass, and one might expect an LAI of approximately 7 to be adequate for interception of 95% of the incident light. Assuming 7 as an adequate LAI, in these experiments only the "hay-type" treatments would provide sufficient cover to intercept 95% of the incident light. This is consistent with the "hay-type" treatments producing the highest yields of forage. Table 3.6 lists leaf area indices for the stubble that remained after each treatment was harvested for yield. The lowest LAI (1.2) was obtained from the stubble of the 12-inch to 2-inch treatment. The 4.5-inch to 3.5-inch and 6-inch to 3.5-inch treatments contained the highest leaf area

Table 3.6. Leaf area index of the total plant and stubble of tall fescue as influenced by height, season, and frequency of defoliation in the third year.

Treat-ments[a] (cut all season)	Total plant			Stubble		
	June	Nov.	Avg.	June	Nov.	Avg.
inches						
3-1.5	4.0[b]	3.5	3.7	2.2	2.2	2.2
3-2	5.2	3.9	4.5	3.2	3.1	3.1
4-2	4.5	4.4	4.5	2.8	2.9	2.9
6-2	5.6	3.6	4.6	2.3	1.6	2.0
12-2	9.2	6.1	7.7	1.5	0.9	1.2
4.5-3.5	4.9	4.9	4.9	4.6	4.6	4.6
6-3.5	4.4	4.8	4.6	3.1	4.0	3.5
12-3.5	11.3	5.7	8.5	1.6	2.4	2.0
LSD[c] (0.05)	1.3	0.9	0.8	0.7	0.8	0.5

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches.
[b] Each value is the mean of four replicates.
[c] LSD = least significant difference.

indices. The 6-inch to 3.5-inch treatment produced an LAI that was 75% higher than that of the 6-inch to 2-inch treatment, yet the higher stubble was 80% taller than the lower stubble. The lower-cut stubble was very efficient in leaf area development per inch of height. Increased disease incidence, particularly *Rhizoctonia*, in treatments permitted to reach a height of 12 inches partially accounted for the thinning of stand and, consequently, the lower LAIs.

Under both the 3.5-inch and 2-inch stubble systems, more frequent clipping regimes produced marked increases in the LAI of the stubble (Table 3.6). For example, the 12-inch to 2-inch, 6-inch to 2-inch, 4-inch to 2-inch, and 3-inch to 2-inch treatments resulted in stubble with LAIs of 1.2, 2.0, 2.9, and 3.1, respectively. Frequent clipping probably produced stubble with more tiller development. Auda *et al*. (1966) have shown that increased light promotes tillering in grasses. The 3-inch to 2-inch defoliation management was more conducive to light penetration than the 4-inch to 2-inch, 6-inch to 2-inch, or 12-inch to 2-inch treatments.

Many researchers have conducted studies relating the growth rate of grasses to the percentage of light intercepted by the herbage and to leaf area. Brougham (1956) stated that the rate of pasture growth increased until complete light interception was approached, and, thereafter, an almost constant maximum rate was sustained. He reported that leaf efficiency (the rate of increase of herbage dry weight per unit area of leaf) was greatly influenced by the intensity of defoliation.

Botanical Analysis of Component Plant Parts

As the frequency and intensity of defoliation increased, there was generally a decrease in the percentage of green blades in the accumulated growth and an increase in stems and sheaths. There was no consistency by treatment on the percentage of dead blades (Table 3.7). A much higher green blade percentage was obtained early in the season (June) for all treatments. As mentioned before, there was a severe drought in the third year. This possibly caused the large increase in dead blades measured in November of the third year. Almost every treatment in November contained twice as many dead blades as in June. Since tall fescue tends to become dormant during the hot, dry months, some increase in drying of leaves would be expected. The least severe treatments (12 inches to 3.5 inches, 12 inches to 2 inches) resulted in the lowest amount of stems and sheaths of the canopy. The 3-inch to 2-inch treatment produced the highest percentage of stems and sheaths in the canopy (51%), and the 12-inch to 3.5-inch treatment produced the lowest percentage of stems and sheaths (25%) when averaged over the year (Table 3.7).

The ratio of the green blades to stems and sheaths for the "hay-type" management systems was different for the canopy and the stubble. For example, the 12-inch to 3.5-inch treatment of the canopy contained approximately 63% green blades and 25% stems and sheaths; yet the stubble contained only 28% green blades and 54% stems and sheaths (Table 3.7). Plants receiving the least frequently clipped treatments (12 inches to 3.5 inches and 12 inches to 2 inches) contained the lowest percentage of green blades and the highest percentage of stems and sheaths in the stubble. There was mutual shading

Table 3.7. Percentage of green blades (GB), stems and sheaths (SS), and dead blades (DB) in the harvested canopy and stubble of tall fescue as influenced by height, season, and frequency of defoliation in the third year.

Treatments[a] (cut all season)	Canopy						Stubble					
	June			November			June			November		
	GB	SS	DB	GB	SS	DB	GB	SS	DB	GB	SS	DB
inches	%						%					
3-1.5	49[b]	43	8	28	56	16	36	56	8	29	54	17
3-2	48	47	5	30	56	14	36	56	8	35	45	20
4-2	45	48	7	38	50	12	39	53	8	31	52	17
6-2	50	43	7	31	53	16	38	50	12	18	58	24
12-2	70	24	6	48	34	18	26	65	9	15	63	22
4.5-3.5	51	46	3	37	46	17	47	45	8	34	42	24
6-3.5	53	44	3	36	40	24	45	49	6	36	43	21
12-3.5	69	24	7	57	26	17	35	56	9	22	53	25
LSD[c] (0.5)	7	6	3	7	6	5	6	9	5	7	9	8

[a] 3-1.5, for example, denotes that tall fescue was cut back to a stubble of 1.5 inches each time growth reached 3 inches.
[b] Each value is the mean of four replicates.
[c] LSD = least significant difference.

between plants in the less severe treatment causing a lowering of the percentage of green blades near the ground surface. Cutting tall fescue all season from 3 inches back to 1.5 inches caused some deterioration in the stand and vigor of the plants, resulting in low green blade percentages and high stem and sheath percentages in the stubble. The invasion of weeds, primarily plantain (*Plantago lanceolata* L.) in the 3-inch to 1.5-inch treatment was further evidence of the gradual decline in vigor and stand under this management. In the spring of the fourth growing season, weeds constituted approximately 15% of the stand in the 3-inch to 1.5-inch treatment and only 2 to 7% in other management treatments cut all season.

The data indicated that the yield from the percentage of green blades and LAI of the stubble for tall fescue cannot be predicted accurately. Stubble height and frequency of defoliation, however, must be taken into consideration. The 4.5-inch to 3.5-inch and 6-inch to 3.5-inch treatments produced a larger percentage of green blades and a larger LAI within their stubble (Tables 3.6 and 3.7) than the comparable 2-inch stubble, but these two treatments produced the lowest total dry matter over a 3-year period. When comparing the LAI of the 3.5-inch stubble with the 2-inch stubble, one must realize that the 3.5-inch stubble is 75% higher than the 2-inch stubble.

Summary and Conclusions

- Resting of tall fescue from June 15 to August 15 (summer rest treatments) generally produced more total dry matter than cutting all season; the increases ranged from 0 to 15%, depending on the management treatment.
- The rest period had very little, if any, effect on spring growth the following year or on later fall growth. Accumulation of food reserves was not as important to growth as the immediate effect of a particular defoliation management during the specific time that the management was being imposed.
- Cutting from 6 inches back to 2 inches was the most productive "grazing-type" treatment in the study, yielding 33% more total dry matter than the 6-inch to 3.5-inch treatment. The least desirable

stubble height for maximum production under "grazing-type" management was 3.5 inches, and the most desirable was 2 inches.
- The average leaf area index of the total plant for two seasons ranged from 8.5 (hay) to 3.7 (grazing). The more frequent clipping regimes (the 3.5-inch and 2-inch stubble defoliations) produced marked increases in the LAI of the stubble. For example, the 6-inch to 2-inch and 3-inch to 2-inch treatments produced stubble with LAIs averaging 2.0 and 3.1, respectively.
- The 6-inch to 2-inch treatment (cut all season) contained a lower percentage of crude protein (19.2%) than the 6-inch to 3.5-inch cutting treatment (21.2%). The crude protein level of the forage from both managements would have been more than sufficient to meet the needs for normal growth of beef cattle.

Study 4. Influence of Defoliation Frequencies on Daily Growth Rate and Associated Nutritive Values

J. C. Burns, Douglas S. Chamblee,
and Francis G. Giesbrecht

Situation

Producers could utilize their tall fescue pastures more effectively during the spring and fall growing periods through intensive grazing management. This grazing strategy has both utilization advantages (Mueller *et al*., 1995) and environmental advantages (Whitehead, 1995) that have economic implications. To implement intensive grazing management, however, producers must subdivide pastures and allocate pasture to animals every day or every several days. This practice permits complete forage utilization over a short grazing period and is followed by a rest period beneficial to regrowth (Harris, 1978). Further, it provides a means of distributing animal waste across the pasture as opposed to concentrating nutrients (point source) around the water supply and in shady areas (Wilkerson *et al*., 1989; Whitehead, 1995).

Intensive grazing, however, requires continuous estimates of:

1. available pasture (to determine land area for each grazing period)
2. relative growth rates for the defoliation intensity used (to determine subsequent rest intervals), and
3. the nutritive value of the pasture (to assess potential daily animal responses).

Such information will permit producers to estimate paddock size and paddock number based on the number of animals and the animal daily performance that may be expected from a specific grazing schedule. Because such data are generally lacking for the piedmont, this study was conducted to determine how a range of defoliation frequencies and intensities affects dry matter (DM) yield, the daily growth rate, and nutritive value of tall fescue during the growing season.

Experimental Procedures

This 3-year study was conducted at the Reedy Creek Road Field Laboratory on a Cecil clay loam soil near Raleigh, N.C. An excellent, well-established stand of Kentucky 31 tall fescue was used for this study. Soil pH was maintained above 6.1, and 80 and 240 pounds per acre of P_2O_5 and K_2O, respectively, were applied every February. A seasonal total of 240 pounds per acre of N was topdressed as ammonium nitrate in split applications of 100 pounds per acre on February 15, 60 pounds per acre on April 15, and 80 pounds per acre on September 15.

Defoliation Treatments and Sampling

Eight defoliation treatments employing mechanical harvesting (Table 4.1) were randomly assigned within each of four replicates in a randomized complete block design. Plots were 6 feet wide and 20 feet long with 5 feet between replicates. The eight treatments consisted of a range of canopy heights defoliated to three different stubble heights throughout the growing season. The date of initial and final defoliation and the number of defoliations varied with treatment and year (Table 4.1). Study 3 in this publication had already established the defoliation effects on the morphology of the tall fescue.

At harvest, a 1-foot-wide strip was removed from the ends of each plot and discarded. A 20-inch-wide by 18-foot-long strip was harvested with a 20-inch rotary mower. The 12-inch to 2-inch and 12-inch to 3.5-inch treatments (Table 4.1) were an exception; those stands were cut with a 2-foot sickle-bar

Table 4.1. Treatment designation, initial and final harvest dates, and number of harvests for each treatment each year.

	Harvest dates								
	Initial date			Final date			Total harvests		
Treatments[a]	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
inches									
3-1.5	4/9	4/6	3/31	10/10	11/5	11/5	10	10	16
3-2	4/9	4/6	3/31	10/10	11/13	11/18	13	14	17
4-2	4/9	4/6	3/31	10/10	11/5	11/5	11	10	15
4.5-3.5	4/9	4/6	3/31	10/17	11/13	11/18	14	15	22
6-2	4/21	4/23	4/9	10/17	11/5	11/18	6	5	8
6-3.5	4/9	4/15	4/9	10/17	11/5	11/5	13	7	12
12-2	4/24	5/5	5/3	10/3	12/1	11/5	4	3	4
12-3.5	4/24	5/5	5/3	10/3	12/1	11/5	4	3	5

[a] 3-1.5, for example, denotes that tall fescue was cut back to a 1.5-inch stubble each time growth reached 3 inches.

mower. The forage harvested with the rotary mower was directly bagged, whereas the forage cut with the sickle-bar mower was raked and placed in a cloth bag. All samples were weighed and dried in a forced-air dryer at 150°F. Then the DM yield was calculated.

Eight subsamples, four spaced along each edge of the harvest strip, were hand cut to the appropriate stubble from each plot, composited, quick frozen in liquid N (-320°F), and placed in a freezer (-13°F). Then samples were freeze-dried, ground in a Wiley mill to pass through a 1-mm screen, and returned to the freezer until analyzed. All samples were analyzed for in vitro dry matter disappearance (IVDMD) (Burns and Cope, 1974), neutral detergent fiber (NDF), acid detergent fiber (ADF), and permanganate lignin (Goering and Van Soest, 1971). Cellulose (CELL) was determined by subtracting lignin plus ash from ADF. Hemicellulose (HEMI) was determined by subtracting ADF from NDF. Samples from the 4-inch to 2-inch, 6-inch to 2-inch, 4.5-inch to 3.5-inch, and 12-inch to 3.5-inch treatments (Table 4.1) were further analyzed for total N (AOAC, 1990) and multiplied by 6.25 and expressed as percent crude protein (CP). Water-soluble carbohydrates (WSC) also were analyzed (Deriaz, 1961).

Changes in Daily Growth Rate and Nutritive Value

The daily growth rate (DGR) was determined for each treatment each year by first plotting the accumulated DM yield during the season on the "Y" axis against each discrete harvest date (Julian) on the "X" axis. Growth was assumed to begin on February 10 each year. A smoothing function was fitted to the accumulated DM yield values and used to compute interpolated daily accumulated yield values. The differences between successive interpolated or predicted yield values were considered estimates of growth rate with respect to time. These values were calculated separately for each treatment, year, and replicate combination (i.e., for each plot). These estimated daily growth rates then were compared during the period when all treatments in all years were present. The additional data collected in early spring and in late October and November for some treatments were included in all figures to show initial and late fall trends. Means and least significant differences (LSDs) for year and treatment were computed for each day, and the results plotted against the dates. Note that the LSDs are point-wise calculations i.e., are calculated for individual days, and, consequently, are valid only at the specific times for which they were computed. Whereas the LSDs for adjacent days are not independent, the changes in LSDs over time provide a valid picture of changes in estimates of mean growth rates across time.

Changes in daily concentrations (%) of IVDMD, CP, WSC, NDF, ADF, HEMI, CELL, and lignin were determined in the same way, and the replotted data fit with a smoothing function to describe the growing season. For completeness, the days between harvest for each treatment each year and the associated dry matter yield and estimate of nutritive values are included in Appendix Tables 4.2 through 4.4. Total dry matter yield for the season was determined by totaling the dry matter yield from each harvest within each treatment. Season crude protein yield and total estimated digestible dry matter (EDDM) yield were determined by multiplying the dry matter yield by the appropriate CP or IVDMD concentration, respectively, for each harvest and by totaling all harvests for each year within a treatment.

Statistical Analyses

An LSD using a pooled error was determined for DGRs and daily concentrations of IVDMD and CP to make comparisons possible among treatments within years. They are presented at 10-day intervals throughout the growing season. An LSD was determined for WSC and NDF and its fiber constituents to make comparisons possible among treatments averaged over all 3 years. An LSD was also determined for making among-year comparisons within the 4-inch to 2-inch, 6-inch to 2-inch, and 12-inch to 2-inch defoliation treatments for 10-day intervals throughout the growing season.

The annual yields of DM, CP, and EDDM were statistically analyzed in a combined analysis for a randomized complete block design with "year" treated as a stripped effect (SAS, 1985). All yield data showed a significant year-by-treatment interaction and were reanalyzed by year and presented by year. A set of six meaningful comparisons (C) was included in the analyses of variance for the annual yields. The 1.5-inch vs. 2.0-inch stubble heights were compared by C_1, and the 2.0-inch and 3.5-inch stubble heights were compared in C_2 (4 inches to 2 inches, 6 inches to 2 inches, and 12 inches to 2 inches vs. 4.5 inches to 3.5 inches, 6 inches to 3.5 inches, and 12 inches to 3.5 inches). Canopy heights within the 2.0-inch stubble were compared in C_3 (12 inches to 2 inches vs. 6 inches to 2 inches and 4 inches to 2 inches) and in C_4 (6 inches to 2 inches vs. 4 inches to 2 inches). Canopy heights within the 3.5-inch stubble height were compared in C_5 (12 inches to 3.5 inches vs. 6 inches to 3.5 inches and 4 inches to 3.5 inches) and in C_6 (6 inches to 3.5 inches vs. 4 inches to 3.5 inches). A minimum significant difference (MSD) from the Waller-Duncan K ratio (K=100) t-test (SAS, 1985) also was included for other comparisons of interest.

Results and Discussion

Temperature in the spring and soil moisture during the growing season are important influences on when growth begins in the spring and the rate at which forage accumulates from one harvest to the next. In general, rainfall was similar each year of the 3-year study. But the differences were of sufficient scope (see Appendix Table 4.1) to alter forage production. This is reflected in the early initial and late final harvest dates noted for year 3 compared with years 1 and 2 (Table 4.1).

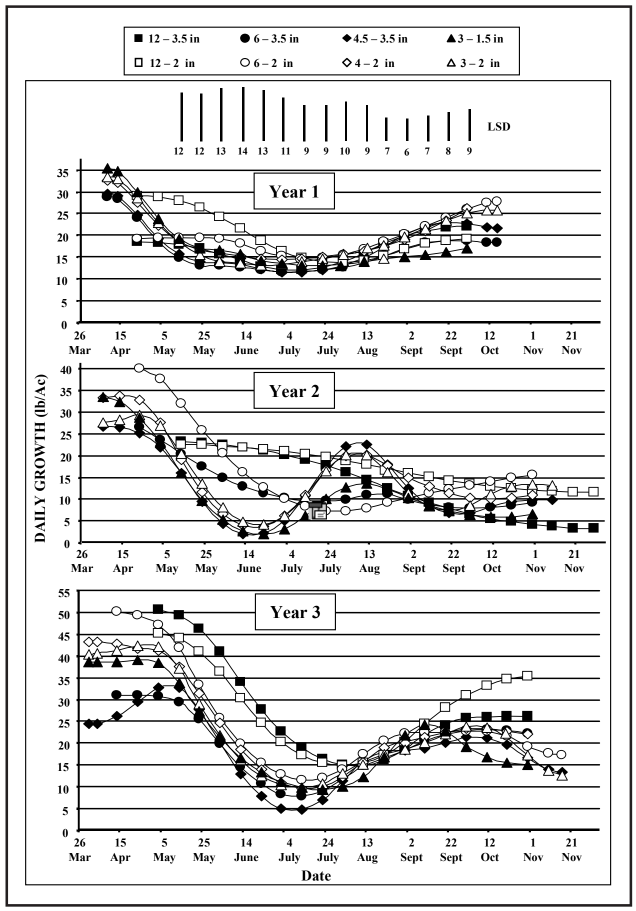

Figure 4.1. Daily growth rate changes of tall fescue by year throughout the growing season resulting from eight defoliation intensities. The LSD ($P \leq 0.05$) applies to all years.

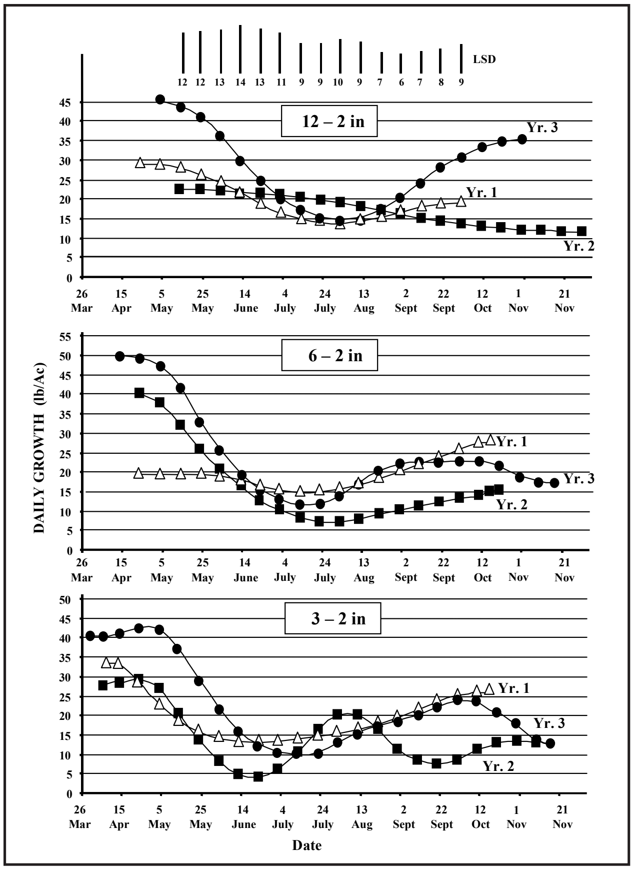

Figure 4.2. Daily growth rate changes among years of tall fescue cut to a 2-inch stubble throughout the growing season. The LSD (P ≤ 0.05) applies to all defoliation treatments.

Seasonal Responses

Annual dry matter yield and associated estimates of nutritive value of tall fescue from defoliation treatments (see Appendix Tables 4.2 through 4.4) are informative regarding the overall forage productivity and its potential for estimating the farm stocking rate. But they are essentially useless for developing intensive grazing systems. The changes in forage growth rates and nutritive value of the new forage growth over increments of 1 week or less throughout the entire growing season are more important. Although only general trends will be discussed for the various measurements, many specific comparisons among defoliation treatments can be made and are left to the interest of the reader.

Daily Growth Rate

The daily growth rate of tall fescue during the growing season differed among defoliation treatments (Figure 4.1) and among years (Figure 4.2) within defoliation treatment, but the year-by-treatment interaction was not significant (P=0.05). Fescue typically grows most quickly during the spring, declines in mid-summer, and resumes growth in the fall. This growth distribution is most representative in year 3 (Figure 4.1). In the third year, the 12-inch to 3.5-inch or 12-inch to 2-inch defoliation treatments showed the highest growth rates into mid-summer with little difference noted thereafter among defoliation treatments until late September. In year 1, except in May, few differences in daily growth rate were noted among defoliation treatments (Figure 4.1) while in year 2 differences during the growing

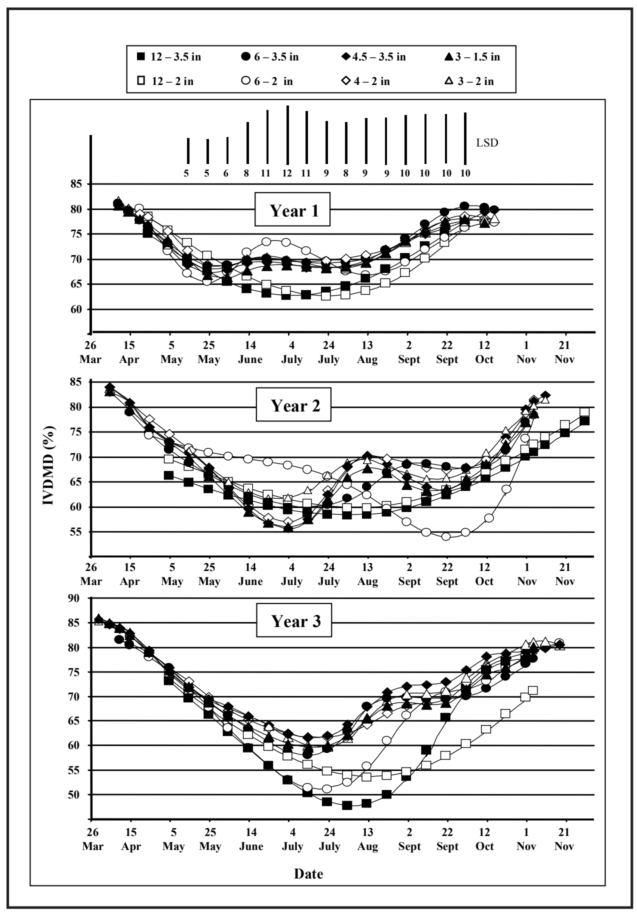

Figure 4.3. Changes in in vitro dry matter disappearance (IVDMD) of tall fescue by year throughout the growing season resulting from eight defoliation intensities. The LSD (P ≤ 0.05) applies to all years.

season were large. In year 2 the less intensive defoliations (12 inches to 3.5 inches or 12 inches to 2 inches) showed trends that were different from the intermediate defoliations (6 inches to 3.5 inches or 6 inches to 2 inches), and both showed different trends than noted for the intensive defoliations (4.5 inches to 3.5 inches, 4 inches to 2 inches, 3 inches to 2 inches, or 3 inches to 1.5 inches). The low growth rate noted in the spring of year 2, especially for the intensive defoliation treatments, followed by increased growth in July and August is attributed, in part, to below normal rainfall in the spring and more favorable rainfall in July and early August (Appendix Table 4.1). The daily growth rate of tall fescue is highly influenced by rainfall and temperature.

The mean daily growth rate during the growing season differed among years within defoliation treatments (Figure 4.2). Because the 3.5-inch and 2-inch defoliation series showed similar year-to-year differences, for simplicity only the 2-inch defoliation treatments are shown here. Large year-to-year differences are noted, with year 3 generally having a higher daily growth rate during the growing season than years 1 or 2. These large year-to-year seasonal differences in the daily growth rate must be given consideration in developing season-long intensive grazing systems to avoid over stocking and in planning an adequate supply of conserved forage for the stocking rate desired. The season-long daily growth rate curves for each treatment each year are presented in Appendix Figure 4.1 to provide an estimate of growth during the early and late portions of the season for the more intensive defoliation treatments. For convenience, the 3-year mean daily growth rate for each treatment for common periods each year is shown in Appendix Figure 4.10. Data in the appendix figures were not analyzed statistically.

Nutritive Value

Defoliation treatments altered the concentrations of all nutritive value estimates determined, although year effects were significant only for IVDMD and CP. The defoliation treatment-by-year interaction was not significant (note: concentration curves for the full seasonal distribution of each variable measured for each treatment for each year are shown in Appendix Figures 4.2 to 4.9; for convenience, the 3-year mean for IVDMD and CP concentrations for each treatment with common periods each year are shown in Appendix Figure 4.10).

In Vitro Dry Matter Disappearance, Crude Protein, and Water-Soluble Carbohydrates

IVDMD was generally lowest during the growing season for the least frequently defoliated treatments (Figure 4.3: 12-inch to 3.5-inch and 12-inch to 2 inch treatments). On the other hand, more frequently defoliated forage (≤ 6 inches) was higher in IVDMD during the growing season and generally similar in concentrations. Results were highly variable across years as noted for the 2-inch defoliation series (Figure 4.4). For example, differences in IVDMD from the 6-inch to 2-inch defoliation treatment on July 4 ranged from about 53.0% in year 3 to about 74.0% in year 1.

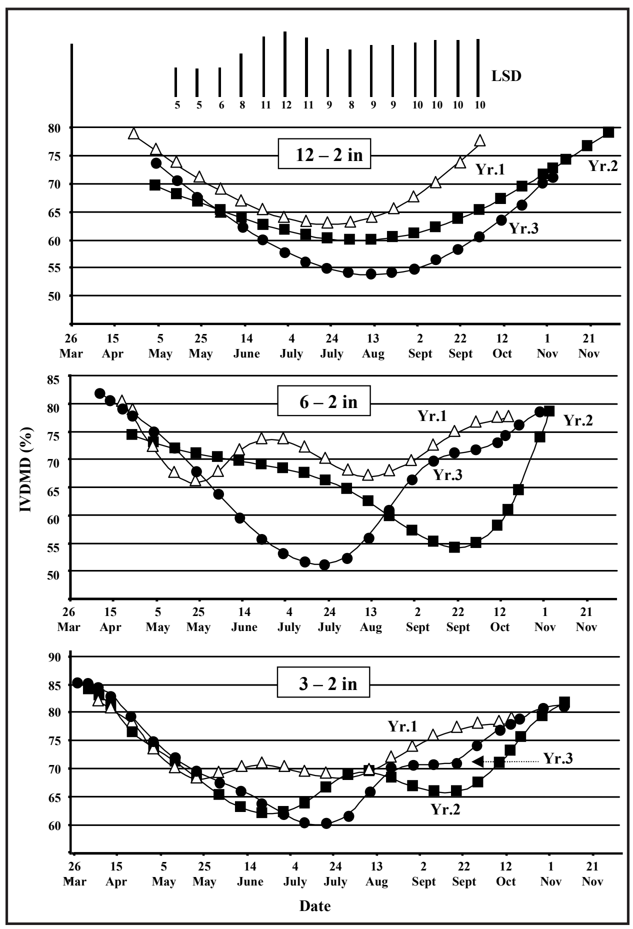

Figure 4.4. Changes in in vitro dry matter disappearance (IVDMD) among years of tall fescue cut to a 2-inch stubble throughout the growing season. The LSD ($P \leq 0.05$) applies to all defoliation treatments.

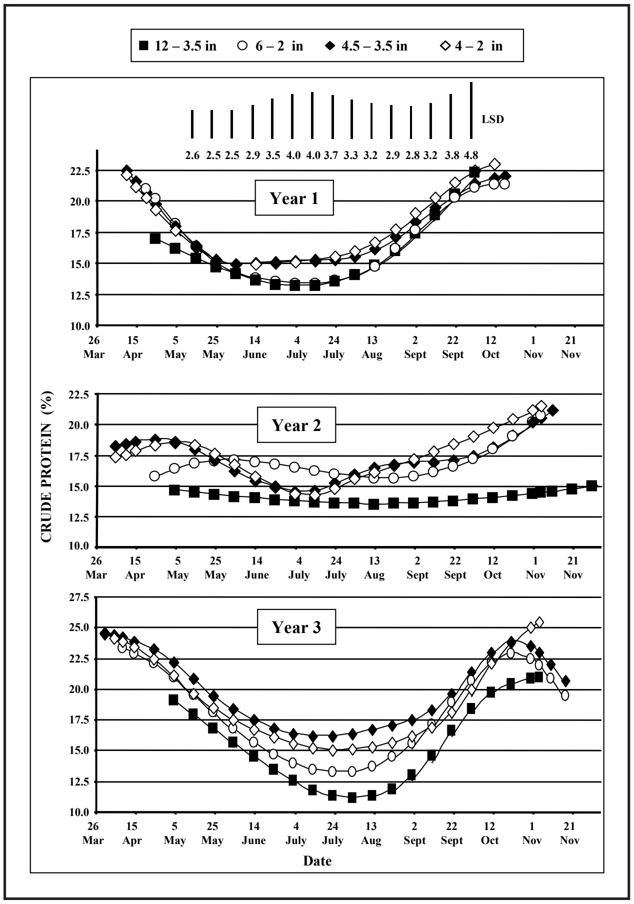

Figure 4.5. Changes in crude protein of tall fescue by year throughout the growing season resulting from four selected defoliation intensities. The LSD ($P \leq 0.05$) applies to all years.

Crude protein concentrations from selected defoliation treatments (12 inches to 3.5 inches, 4.5 inches to 3.5 inches, 6 inches to 2 inches, and 4 inches to 2 inches) were similar during the growing season in year 1 (Figure 4.5) but were numerically lower for the 12-inch to 3.5-inch defoliation treatment in years 2 and 3. Higher CP concentrations in the forage occurred during the growing season from the more frequent defoliation treatments in year 3. CP concentrations during the growing season varied significantly across the years as shown for selected treatments (Figure 4.6). Defoliation treatments that result in a CP concentration of < 15.0% during the growing season may limit the performance of calves weighing from 300 to 500 pounds, which obtain most of their daily nutrients from pasture (NRC, 1984). In some years (Figure 4.6), CP concentrations of some treatments in the summer fell below 15.0% and in one case dropped to 11.0%.

Water-soluble carbohydrates were altered by defoliation treatments as noted from the selected treatments analyzed (Figure 4.7: 12-inch to 3.5-inch, 4.5-inch to 3.5-inch, 6-inch to 2-inch, and 4-inch to 2-inch treatments). Differences emerged by July 4 and existed through early September. The 12-inch to 3.5-inch defoliation resulted in a consistently lower WSC concentration; it averaged only 8.0% in July and increased slowly to more than 9% by early September. More frequent defoliation increased WSC from about 9.0 to 12.5% or higher during the same period. This trend is generally reflected in increased IVDMD from July to September.

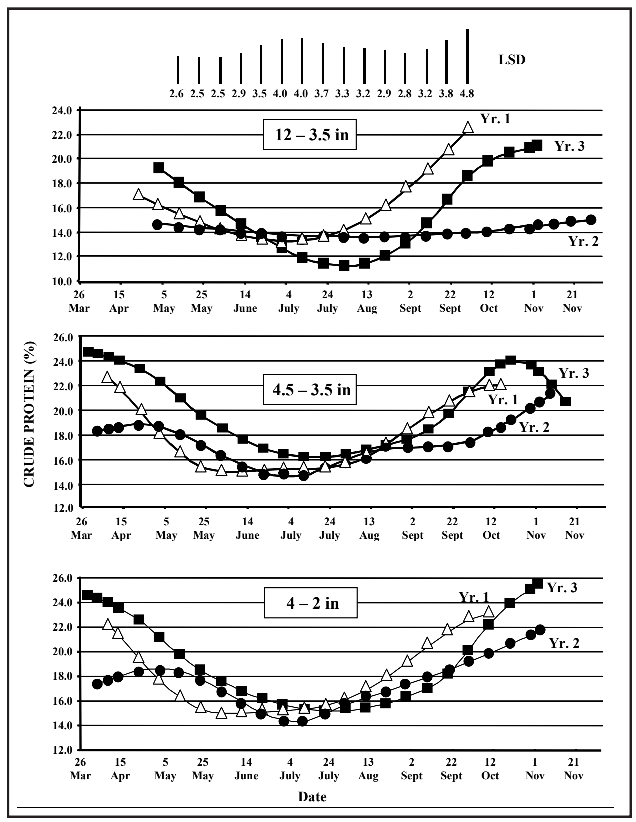

Figure 4.6. Changes in crude protein among years of tall fescue cut at three selected defoliation intensities throughout the growing season. The LSD ($P \leq 0.05$) applies to all defoliation treatments.

Neutral Detergent Fiber and Constituent Fractions

Defoliation treatments altered NDF and constituent fiber concentrations of the forage (Figures 4.7 and 4.8). The least intensive defoliation treatments (12 inches to 3.5 inches, 12 inches to 2 inches) generally resulted in forage with the highest NDF and constituent fiber concentrations during the growing season while the more intensive defoliation treatments produced forage with lower concentrations. The noted exception was for lignin (Figure 4.8); the 3-inch to 1.5-inch defoliation treatment resulted in forage with large increases in lignin in May through July. The cause of this response is not clear but may be associated with higher lignin concentrations present in basal stems. Little difference in NDF and associated fiber concentrations was noted among the four more intensive defoliation treatments (4.5 inches to 3.5 inches, 4 inches to 2 inches, 3 inches to 2 inches, and 3 inches to 1.5 inches) during the growing season.

Figure 4.7. Changes in water-soluble carbohydrates (WSC), neutral detergent fiber (NDF), and constituent acid detergent fiber (ADF) of tall fescue cut at multiple defoliation intensities throughout the growing season (mean 3 years) (LSD; P ≤ 0.05).

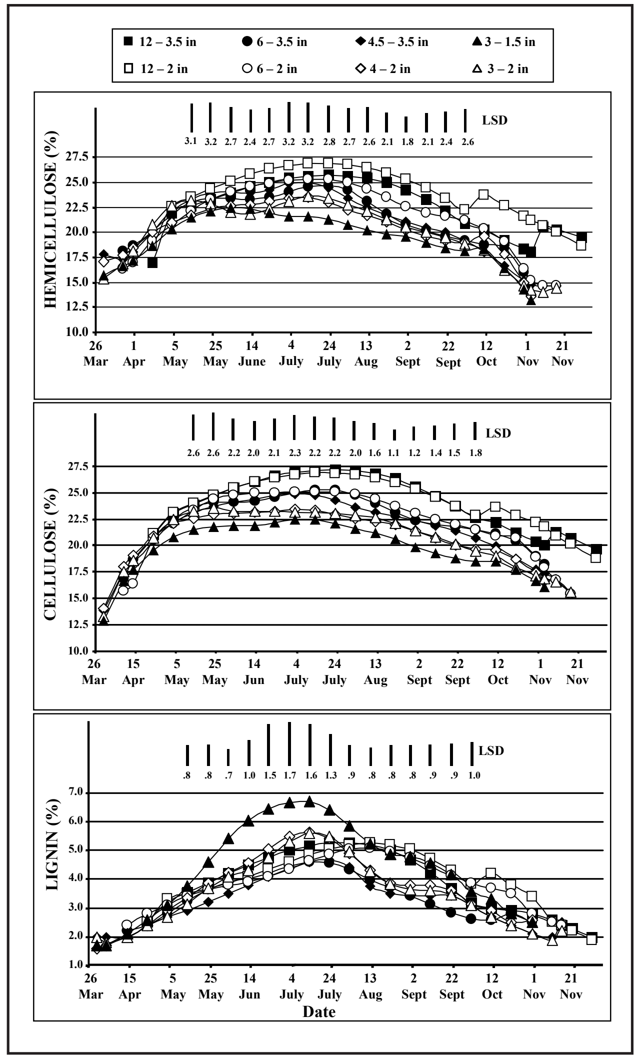

Figure 4.8. Changes in hemicellulose, cellulose, and lignin of tall fescue cut at eight defoliation intensities throughout the growing season (mean 3 years) (LSD; P ≤ 0.05).

Application

Changes in the tall fescue growth rate, both those that occur during the grazing season and those caused by defoliation treatments, indicate that producers must take certain steps if animal numbers are to remain nearly constant during the grazing season. Paddock size or rotation interval, or both, must be adjusted from spring to summer to fall, depending on the animal response targeted by the manager. This indicates the need to develop flexible grazing systems using variable stocking.

Summary and Conclusions

- Comparisons among eight defoliation treatments at 10-day intervals during the growing season showed major differences in the forage growth rate (pounds per acre per day) as well as its nutritive value. The difference among defoliation treatments varied in size from year to year.
- Altering the forage growth rate and nutritive value during critical stress periods during the summer through defoliation intensity was possible and may be of more economic advantage than simply generating greater annual forage production.
- Defoliation intensity significantly ($P < 0.01$) altered annual dry matter production and associated nutritive value of tall fescue. The less intensive defoliation treatments resulted in greater annual dry matter yields but reduced nutritive value estimates compared to the more intense treatments.
- The changes noted in the daily growth rate of tall fescue, both during the grazing season and from year to year, among defoliation treatments indicate why variable stocking is important when pasture is the sole source of nutrients.

Summer Accumulation for Fall Utilization

Study 5. Yields and Nutritive Value of Tall Fescue from Different Periods of Summer Accumulation and Subsequent Effects on Spring Production

J. C. Burns and Douglas S. Chamblee

Situation

As night-time temperatures cool in late August, tall fescue resumes growth and continues growing into December. Although this growth period is less productive than the spring growth period (March to June), it does provide forage that can be accumulated and rationed for grazing in late October through March. This feature can be advantageously used in a production system in which warm-season grasses provide pasture from late April until late September.

This study was conducted to determine how the date that tall fescue accumulation begins in late summer influences dry matter yield and nutritive value by mid-November. It also evaluated how repeated late summer accumulation on the same site affected dry matter yield in November and evaluated the influence of repeated fall accumulation (stockpiling) treatments on subsequent spring production.

Experimental Procedures

This experiment was conducted at the Reedy Creek Road Field Laboratory near Raleigh, N.C. The site was a Cecil clay loam soil topdressed with 3,000 pounds per acre of dolomitic limestone and 21, 60, and 60 pounds per acre of N, P, and K, respectively, at seeding. Kentucky 31 tall fescue was uniformly seeded at 44 pounds per acre, and an excellent stand was obtained. Sufficient land was seeded and uniformly managed in the experiment to permit previously unused land to be used for initial forage accumulation in the fall for each of 3 years. The study was conducted over 5 years, however, to obtain carryover effects.

Treatments and Sampling

Five treatments were evaluated in a randomized complete block design with four replicates. The treatments consisted of four periods of forage accumulation beginning on June 1, July 1, August 1, and September 1. The fifth treatment was a N rate variable with 60 pounds of N per acre applied at the July 1 accumulation date. It is referred to as J+N.

The experiment was topdressed annually with 71 and 130 pounds per acre of P_2O_5 and K_2O, respectively. All plots received 100 pounds of N per acre on March 1 and 80 pounds of N per acre on August 25 as a topdressing of ammonium nitrate for a seasonal total of 180 pounds of N per acre. Nitrogen application for fall growth was delayed until August to avoid potential stand losses previously experienced with high N applications in June or July. The modest application of 60 pounds of N per acre at the July 1 accumulation date resulted in a seasonal total of 240 pounds of N per acre for that treatment. Dry matter (DM) yields were measured in mid-November, and samples were obtained for nutritive value estimates.

The experiment was initiated on a 2-year-old stand the first fall by uniformly harvesting the entire experimental area to a 2-inch stubble until June 1 and discarding the forage. Then the forage was removed from the area designated for year 1 up to the appropriate accumulation date. The unused areas designated for initial stockpiling in years 2 and 3 were kept uniformly harvested during the study until their use. Each plot (6.2 feet by 15 feet) was halved (3.1 feet) and one-half was randomly assigned either for yield estimates or for monthly sampling to determine changes in nutritive value during the fall and winter.

Yield estimates were obtained only in mid-November by harvesting a 2-foot by 15-foot swath with a sickle-bar mower set to cut at a 2-inch stubble. Visual estimations of the percentage of green and brown tall fescue and weeds were made before each harvest. The yield data reported for tall fescue are weed-free. The harvested weight from each plot was recorded; a subsample was obtained, and it was dried at 167°F and used for DM yield determination.

The other half of the plot, designated to estimate changes in nutritive value of the accumulated forage, was sampled monthly from October through early March. Only the nutritive value of the November yield harvest is presented in this study. See Study 6 for sampling details and changes in nutritive value of the accumulated forage from October to March.

Carryover Effects

The study investigated whether repeating summer accumulation year after year on the same land area would reduce dry matter yields. This was done by continuing the same accumulation treatments on the plots used initially in year 1 (repeated years 2, 3, and 4), year 2 (repeated years 3 and 4), and year 3 (repeated year 4). The potential carryover effect of summer accumulation on the subsequent spring's growth was also examined. This was achieved by obtaining the DM yields in the spring (year 2) from the same plots used for the initial summer accumulation (year 1) and for the next three springs (ending year 5) following subsequent repeated summer accumulation on the same plots. All plots were harvested uniformly in the spring when forage reached about 10 inches and were cut back to a 2-inch stubble, with the last harvest occurring by June 1 (the first initiation date for summer accumulation). Subsequent regrowth on plots of the other initiation dates was discarded as appropriate. Consequently, the seasonal DM production from tall fescue can be estimated only for the June 1 treatment by adding the spring yield and the DM accumulated by mid-November of the same year.

Nutritive Value

Samples were obtained for chemical analyses by hand cutting fescue along the edge of the November harvest strip to a 2-inch stubble. Samples were immediately quick frozen in liquid nitrogen (-320°F) and transferred to a freezer (-13°F) for storage. Then they were freeze-dried, ground in a Wiley mill to pass through a 1-mm screen, and returned to the freezer until analyzed. Samples were analyzed for in vitro dry matter disappearance (IVDMD) according to Burns and Cope (1974), and neutral detergent fiber (NDF), acid detergent fiber (ADF), permanganate lignin, and neutral detergent ash were analyzed according to Goering and Van Soest (1971). Cellulose (CELL) and hemicellulose (HEMI) were determined by difference. Total N was determined (AOAC, 1990) and multiplied by 6.25 and expressed as percent crude protein. Samples from selected treatments and sampling dates were analyzed for total nonstructural carbohydrates (TNC) according to Smith (1969).

Statistical Analyses

Data were statistically analyzed in combined analyses (over years) for a randomized complete block design. When treatments interacted with years, the analyses were conducted by year and the data were presented by year. The analysis of variance included a time trend (the J+N treatment excluded) for length of accumulation [linear (L) and quadratic (Q)] and a N rate comparison for the July 1 accumulation date (July 1 vs. J+N). A minimum significant difference (MSD) from the Waller-Duncan K ratio (K = 100) t-test (SAS Institute, 1985) also was determined and included for other comparisons of interest.

Results and Discussion

Soil moisture has an important influence on the quantity of DM that can be accumulated for late fall-winter utilization. During this study rainfall varied appreciably (see Appendix Table 5.1). In year 1, above-average rainfall occurred in June while below-average rainfall occurred the rest of the season until the November harvest. Temperatures were below average in July and August, then above average through November. This would favor accumulation from the June 1 initiation date. Rainfall was near average during June, August, and September in year 2, but below average in July, October, and November. Temperatures were below average from June through November. This pattern could result in similar dry matter yields from the July 1 and August 1 accumulation dates. Rainfall during year 3 was variable, being above average in July, September, and November but below average in June, August,

Summer Accumulation for Fall Utilization

Table 5.1. Dry matter yield of tall fescue harvested in mid-November following four summer accumulation dates from each of three areas not previously used for stockpiling. Also, associated portion of green tissue, weeds, and green tissue yield (oven-dry basis).[a]

	Area 1, yr 1	Area 2, yr 2				Area 3, yr 3			
Accumulation date	Dry matter yield	Dry matter yield	Green tissue	Weeds	Green yield	Dry matter yield	Green tissue	Weeds	Green yield
	lb/ac	lb/ac	%	%	lb/ac	lb/ac	%	%	lb/ac
June 1	4,860[b]	3,630	54	10	1,760	4,040	67	2	2,660
July 1 (J)	3,110	3,090	55	11	1,510	3,760	67	2	2,470
J+N[c]	4,290	4,040	51	5	1,970	4,980	50	4	2,350
Aug. 1	2,610	3,120	56	8	1,600	2,870	71	6	1,920
Sept. 1	900	760	70	5	510	2,770	77	1	2,110
Significance									
Trend[d]	L	Q	Q	NS	Q	L	L	NS	L
J vs. J+N	<0.01	<0.01	NS	NS	<0.01	<0.01	<0.01	NS	NS
MSD[e]	530	510	7	—	270	440	6	—	540
Mean[f]	3,150	2,930	57	8	1,470	3,680	66	3	2,300
CV %[g]	11.8	12.2	8.2	51.7	10.5	8.4	6.5	133.0	13.8

[a] The dry matter and green yield data are reported on a "weed-free" basis. The green yield data are weighted for individual harvest, consequently, simply multiplying dry matter yield by the percentage of green tissue will not equal the green yield reported.
[b] Each value is the mean of four replicates.
[c] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds applied to all treatments on August 25.
[d] L = linear and Q = quadratic (J+N not included); NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan K-ratio (K = 100) t-test.
[f] Each value is the mean of five treatments and four replicates (n = 20).
[g] CV = coefficient of variation.

and October. Temperatures were above average in August through November. This pattern would favor DM yields from the July and September accumulation dates. In year 4, below-average rainfall occurred during the accumulation months of June, July, and August but above-average rainfall occurred in September and October. Temperatures were below average in August through November. This would favor the accumulation of forage from the September 1 accumulation date, but would tend to remove differences in dry matter yields from the July 1 and August 1 accumulation dates.

Initial Fall Yields

November yields from plots used the first time for summer accumulation of tall fescue ranged from 760 to 4,980 pounds per acre (Table 5.1). As the initiation date for summer accumulation was delayed from June 1 through September 1, yields decreased linearly in years 1 and 3. Yields in year 1 averaged 252 pounds per acre less for every week that accumulation was delayed. In year 3 the reduction was 95 pounds per acre for every week that accumulation was delayed. The response in year 2 was quadratic and resulted from no change in yield when the initiation date was delayed from July 1 to August 1. Monthly rainfall patterns and temperature (Appendix Table 5.1) favored higher dry matter yields in year 3.

The application of additional N on July 1, compared with adding none on that date, increased yields in all years an average of 1,117 pounds per acre

(Table 5.1). The response averaged 18.6 pounds of DM per pound of N applied.

Delaying forage accumulation until September 1 resulted in yields of 900 pounds per acre or less in years 1 and 2. In year 3, yields for the September 1 accumulation were much higher (2,770 pounds per acre) and were attributed, in part, to above-normal rainfall in both September and November (Appendix Table 5.1).

The proportion of green tissue, important relative to nutritive value, was determined in mid-November in years 2 and 3 and averaged 57 and 66%, respectively (Table 5.1). One striking difference among the accumulation treatments was the lower proportion of green tissue in the J+N treatment. Another was the highest proportion of green tissue occurring in the September 1 accumulated forage. Year 3 was much more extreme than year 2. The green tissue yields

Table 5.2. Changes in concentrations of in vitro dry matter disappearance (IVDMD), crude protein (CP), total nonstructural carbohydrates (TNC), neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEMI), cellulose (CELL), and lignin in tall fescue forage accumulated from four summer accumulation dates and harvested mid-November (oven-dry basis).

Item	IVDMD	CP	TNC[a]	NDF	ADF	HEMI	CELL	Lignin
	%							
Accumulation date[b]								
June 1	62.0	12.6	8.9	54.3	31.3	23.0	24.7	5.5
July 1 (J)	64.0	12.7	9.1	52.3	31.6	20.7	25.4	5.2
J+N[c]	56.6	13.2	8.2	55.1	32.7	22.5	25.7	6.0
Aug. 1	67.0	12.8	10.4	49.6	28.3	21.3	23.5	3.8
Sept. 1	71.1	12.8	12.7	46.3	37.3	19.0	24.7	4.3
Significance								
Trend[d]	L	NS	Q	L	L	L	Q	L
J vs. J+N	<0.01	0.09	NS	NS	NS	NS	NS	NS
MSD[e]	3.8	—	1.5	3.8	1.6	3.6	1.3	1.0
Year[f]								
1	66.2	14.8	8.8	47.2	29.1	18.1	23.3	4.6
2	63.0	10.9	11.6	52.7	30.1	22.6	23.9	5.1
3	63.3	12.8	9.2	54.8	31.7	23.1	25.6	5.2
Significance								
MSD	NS	1.3	1.2	4.7	2.3	NS	12.0	NS
Mean[g]	64.2	12.8	9.9	51.5	30.3	21.3	24.3	5.0
CV (%)[h]	4.3	9.0	12.5	5.1	4.8	9.5	3.7	13.8

[a] TNC was determined on forage sampled October 15.
[b] Each value for IVDMD is the mean of 3 years and four replicates (n = 12). For the other variables, each value is the mean of 3 years and three replicates (n = 9).
[c] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[d] L = linear and Q = quadratic (J+N not included), NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[f] Each value for IVDMD is the mean of five treatments and four replicates (n = 20). The other variables are the mean of five treatments and three replicates (n = 15).
[g] Each value for IVDMD is the mean of five treatments, 3 years, and four replicates (n = 60). The other variables are the mean of five treatments, 3 years, and three replicates (n = 45).
[h] CV = coefficient of variation.

showed similar trends to those noted for yields in both years 2 and 3.

Weeds generally were not a problem, ranging from 8% of dry matter in year 2 to 3% in year 3 (Table 5.1). In neither year did the date for summer accumulation have any influence on the proportion of weeds present.

Nutritive Value

In November, the IVDMD of accumulated forage ranged from 62.0% for the June 1 accumulation to 71.1% in the September 1 accumulation and averaged 64.2% for the 3-year study (Table 5.2). The IVDMD increased linearly ($P < 0.05$) as the date for summer accumulation was delayed, averaging a 3.0 percentage-unit increase for every 30-day delay in accumulation from June 1 to September 1. Associated with the increase in IVDMD was a quadratic increase in TNC, ranging from 8.9 to 12.7%. The NDF concentration decreased 2.6 percentage units for every 30-day delay in accumulation from June 1 to September 1. The IVDMD of the September 1 accumulated forage averaged 71.1%, and as long as the accumulated forage retains its nutritive value it should support acceptable daily gains for replacement heifers or growing steers. This is also true for the August 1 accumulation, which was lower at 67.0% IVDMD. Forage from the June 1 and July 1 accumulations had similar IVDMD of 62.0 and 64.0%, respectively, and probably would be lacking adequate energy for wintering growing stock. Applying additional N at the July 1 starting date resulted in the lowest IVDMD of 56.6%, but produced the highest DM yields (Table 5.1). This forage should maintain growing stock, but is more appropriately used to support mature cows.

Crude protein concentrations by mid-November showed no change among the summer accumulation treatments, averaging 12.8% for the 3-year study. There was, however, an appreciable difference in CP concentrations among the 3 years (Table 5.2). By November, summer-accumulated forage averaged 14.8% CP in year 1 and 12.8% CP in year 3 regardless of the accumulation period (Table 5.2). Because of conditions in year 2, accumulated forage without an additional N application never exceeded 10.6% CP in November (data not shown) and might have been marginally adequate for nutrient requirements of growing stock. In year 2, the addition of N at the July 1 starting date resulted in CP concentrations of 12.2% (data not shown). This management strategy may be a way to guard against inadequate CP concentrations in some years. The other fiber constituents (ADF, HEMI, CELL, and lignin) showed similar responses as noted for NDF (Table 5.2).

Fall Yields from Repeated Summer Accumulation

Following the initial year of summer accumulation on experimental area one, DM yields ranged from 960 to 5,170 pounds per acre after repeated years of accumulation on the same plots (Table 5.3). Adverse carryover effects from repeating the same accumulation treatment on the same plot cannot be directly determined because of the changes in rainfall and temperature patterns during the study.

Examination of the data, however, strongly indicates that carryover effects were minimal. First, almost all of the mean yields of the three repeat years (Table 5.3) are numerically greater than yields in the initial year. Secondly, almost all of the yields in repeat year 4 of these treatments are numerically similar to, or greater than, those of the summer accumulation from plots used in the first year (Table 5.3). This was not true, however, for the June 1 initiation date. This date was highly favored in the first year of accumulation, giving highest ($P < 0.05$) yields averaging 4,860 pounds per acre (Table 5.3). This was not repeated in years 2 or 3 from initial accumulation areas (Table 5.1), which correspond to repeat years 2 and 3 of the initial year 1 stockpile area (Table 5.3). The June 1 harvests accumulated 3,630 pounds per acre in year 2 and 4,040 pounds per acre in year 3 (Table 5.1), which corresponds closely to the 3,740 and 3,970 pounds per acre obtained in repeat years 2 and 3 under identical growing conditions.

This consistency, along with the same patterns of greater yields from the July 1 + N accumulation date and least yields from the September 1 accumulation date, suggest that the June 1 discrepancy in the initial year is mainly due to the environment and not an adverse accumulation influence. Combining the 3 years of the initial year for summer accumulation (Table 5.1) and adding in the repeated years of accumulation (Table 5.3 and Appendix Table 5.2)

Table 5.3. Mean initial dry matter yield harvested in the first year of accumulation in mid-November from experimental area one. Also, repeated accumulated yields harvested in mid-November from the same area for 3 years with associated proportion of the harvested tall fescue that remained green, green dry matter yield, and weeds (oven-dry basis).[a]

Accumulation date	Dry matter yield					Green fescue			Green DM yield			Weeds		
	Initial year	Repeated				Repeated			Repeated			Repeated		
		Y2	Y3	Y4	Mean	Y2	Y3	Y4	Y2	Y3	Y4	Y2	Y3	Y4
	.... lb/acre					..... %			..... lb/acre			..... %		
June 1	4,860[b]	3,740	3,970	3,330	3,680	61	62	71	2,220	2,440	2,270	3	2	4
July 1 (J)	3,110	3,170	3,890	2,760	3,273	61	63	75	1,830	2,380	1,900	5	2	7
J+N[c]	4,290	4,170	5,170	4,490	4,610	59	59	68	2,350	3,020	2,980	4	2	2
Aug. 1	2,610	3,070	3,310	2,570	2,983	64	60	58	1,870	1,940	1,880	6	3	4
Sept. 1	900	960	2,740	1,780	1,827	76	68	74	700	1,820	1,310	5	1	4
Significance														
Trend[d]	L	Q	Q	L		Q	NS	NS	Q	L	L	NS	NS	NS
J vs. J+N	< 0.01	< 0.01	< 0.01	< 0.01		NS	NS	NS	< 0.01	0.03	< 0.01	NS	NS	NS
MSD[e]	530	410	272	440		4	—	—	303	549	347	—	—	—
Mean[f]	3,150	3,020	3,820	2,990	3,275	64	62	69	1,790	2,320	2,070	5	2	4
CV (%)[g]	11.8	9.6	5.1	10.3		4.6	15.4	23.1	11.9	15.3	11.7	65.0	74.2	83.9

[a] The dry matter and green yield data are reported on a "weed-free" basis. The green yield data are weighted for individual harvest, consequently, simply multiplying dry matter yield by the percentage of green tissue will not equal the green yield reported.
[b] Each value is the mean of four replicates.
[c] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[d] L = linear and Q = quadratic (J+N not included); NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[f] Each value is the mean of five treatments and four replicates (n = 20).
[g] CV = coefficient of variation.

provides nine estimates of dry matter yield from the accumulation treatments. Yields dropped 127 pounds per acre for every week that accumulation was delayed from June 1 to September 1.

The application of an additional 60 pounds N per acre on July 1 increased yields in all years (initial year plus the three repeat years for area 1), averaging 1,298 pounds per acre more dry matter (Table 5.3). This practice returned on the average 21.6 pounds of dry matter per acre for every pound of nitrogen applied per acre. Considering the initial and repeat years for both experimental areas two and three (presented for completeness in Appendix Table 5.2), the application of an additional 60 pounds of N per acre resulted in an average of 1,526 pounds per acre more dry matter yield or 25.4 pounds of dry matter per pound of N applied.

Green tall fescue tissue in the stockpile averaged from 62 to 69% of the harvested DM. This measurement was not taken in the initial year of the stockpile, but trends among treatments within years were similar (Table 5.3). In repeat year 2, the proportion of green tissue in the stockpile increased as the period of accumulation was reduced, whereas in repeat years 3 and 4, differences were not significant.

Green tissue dry matter yields ranged from 1,790 to 2,320 pounds per acre during the repeat years 2 through 4 (Table 5.3). Yields of green tissue decreased as initiation date was delayed in repeat years 3 and 5. As noted for the first time of accumulation, the application of an additional 60 pounds of N per acre on July 1 increased green tissue dry matter yields in all repeat years averaging 747 pounds per

Table 5.4. The influence of the previous summer's repeated accumulations on subsequent spring dry matter yield. The data are from four accumulation starting dates in experimental area one (oven-dry basis).

Accumulation date	Spring, year 2			Spring, year 3				Spring, year 4			Spring, year 5			
	April 2	May 29	Total	April 10	May 7	June 2	Total	April 20	June 1	Total	April 21	May 23	June 22	Total
	lb/acre			lb/acre				lb/acre			lb/acre			
June 1	2,070[a]	2,660	4,720	800	1,060	230	2,090	1,620	1,100	2,720	2,730	650	230	3,610
July 1 (J)	1,920	2,780	4,690	760	1,040	260	2,060	1,730	1,180	2,900	2,840	670	230	3,740
J+N[b]	1,940	2,920	4,870	860	1,100	260	2,220	1,600	1,230	2,820	3,180	680	310	4,170
Aug. 1	2,270	2,810	5,080	810	1,090	250	2,150	1,600	1,210	2,810	2,960	640	240	3,850
Sept. 1	2,130	2,680	4,800	830	1,100	230	2,150	1,590	1,210	2,800	2,950	650	240	3,840
Significance														
Treatment	0.19	0.14	0.25	0.52	0.74	0.75	0.45	0.70	0.46	0.70	0.06	0.96	0.22	0.08
MSD[c]	—	—	—	—	—	—	—	—	—	—	330	—	—	440
Mean[d]	2,070	2,770	4,830	810	1,080	240	2,130	1,630	1,180	2,810	2,930	660	250	3,840
CV (%)[e]	10.2	5.3	5.1	10.0	6.9	17.2	5.9	9.3	8.9	6.2	6.5	11.5	19.9	6.5

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[d] Each value is the mean of five treatments and four replicates (n = 20).
[e] CV = coefficient of variation.

Table 5.5. Mean dry matter yield for the spring growth (through June 1) and when repeatedly accumulated from four summer dates and harvested mid-November from experimental area one (oven-dry basis).

Accumulation date	Season, year 2		Season, year 3		Season, year 4	
	Spring	Fall	Spring	Fall	Spring	Fall
	.... lb/acre		.... lb/acre		.... lb/acre	
June 1	4,720[a]	3,740	2,090	3,970	2,720	3,330
July 1 (J)	4,690	3,170	2,060	3,890	2,900	2,760
J+N[b]	4,870	4,170	2,220	5,170	2,820	4,490
Aug. 1	5,080	3,070	2,150	3,310	2,810	2,570
Sept. 1	4,800	960	2,150	2,740	2,800	1,780
Significance						
Trend[c]	NS	Q	NS	Q	NS	L
J vs. J+N	—	< 0.01	—	< 0.01	—	< 0.01
MSD[d]	—	410	—	272	—	440
Mean[e]	4,830	3,020	2,130	3,820	2,810	2,990
CV (%)[f]	5.1	9.6	5.9	5.1	6.2	10.3

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear and Q = quadratic (J+N not included); NS = not significant.
[d] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[e] Each value is the mean of five treatments and four replicates (n = 20).
[f] CV = coefficient of variation.

acre. This resulted in 12.5 pounds of green tissue DM for every pound of nitrogen applied per acre. The September 1 accumulation gave lowest green tissue yields. In repeat year 3, however, the August 1 and September 1 green tissue DM yields were similar.

After 4 years of stockpiling on the same land site, weeds ranged from 2 to 5% of the DM (Table 5.3). No differences were noted among the accumulation treatments. The prevalence of weeds was variable, however, as indicated by the magnitude of the coefficients of variation (CVs) (Table 5.3).

Repeated Summer Accumulation and Subsequent Spring Yields

Repeated accumulation on experimental area one provided four estimates of spring carryover effects (Table 5.4). The five summer accumulation treatments showed no hint of carryover effects on the first subsequent spring harvest until year 5. In year 5 there might have been some indications of N carryover evident in the J+N treatment, but it is not clear if it was an emerging trend or simply due to a unique environmental occurrence.

The data from experimental areas two and three (Appendix Tables 5.3 and 5.4) also showed evidence of some carryover occurring from the J+N treatment. The spring yield data in year 4 from experimental area two (Appendix Table 5.3) showed that the DM yields from the harvest taken June 1 of the J+N treatment was higher than that obtained on the same date from the June 1 treatment (1,120 vs. 970 pounds per acre). This effect also was noted for the April 21 yields obtained in year 5 (3,170 vs. 2,690 pounds per acre). Differences in spring DM yields were not statistically significant among summer accumulation treatments evaluated in experimental area three (Appendix Table 5.4).

Seasonal Dry Matter Yields

Seasonal DM yields can be estimated by adding the spring growth through June 1 with the subsequent accumulated growth from June 1 through November 15 for the June 1 accumulation treatment. The

Table 5.6. Mean dry matter yield for the spring growth (through June 1) and when repeatedly accumulated from four dates and harvested mid-November from experimental areas two and three (oven-dry basis).

Accumulation date	Experimental area 2				Experimental area 3	
	Season, year 3		Season, year 4		Season, year 4	
	Spring	Fall	Spring	Fall	Spring	Fall
	.... lb/acre		.... lb/acre		.... lb/acre	
June 1	1,890[a]	3,490	2,420	2,980	2,450	3,400
July 1 (J)	1,910	3,490	2,760	2,370	2,520	2,600
J+N[b]	2,190	4,970	2,690	4,250	2,560	4,700
Aug. 1	2,150	3,070	2,710	2,390	2,580	2,180
Sept. 1	1,950	2,610	2,670	1,560	2,850	1,660
Significance						
Trend[c]	NS	L	NS	L	NS	L
J vs. J+N	—	< 0.01	—	< 0.01	—	< 0.01
MSD[d]	—	430	—	470	—	640
Mean[e]	2,020	3,530	2,650	2,710	2,590	2,910
CV (%)[f]	13.0	8.6	5.9	12.3	13.2	15.3

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear (J+N not included); NS = not significant.
[d] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[e] Each value is the mean of five treatments and four replicates (n = 20).
[f] CV = coefficient of variation.

seasonal yields from years 2, 3, and 4—which are yields from treatments repeated on experimental area one—were 8,460, 6,060, and 6,050 pounds per acre, respectively (Table 5.5). Seasonal DM yields estimated by the June 1 accumulation treatment repeated in years 3 and 4 on experimental area two and year 4 on experimental area three averaged 5,380, 5,400, and 5,850 pounds per acre, respectively (Table 5.6). Because the forage produced between June 1 and the initiation dates for accumulation from July 1, August 1, and September 1 was not measured, the seasonal DM yields for those treatments are underestimated.

Summary and Conclusions

Tall fescue can be readily accumulated for forage in the summer in the piedmont of North Carolina beginning as early as June 1. In this study, the summer N topdressing was deferred until August 25, except for one treatment that received an extra application on July 1.

- Accumulating growth from June 1 resulted in the highest DM yield by mid-November (mean = 4,180 pounds per acre) in 2 of the 3 years evaluated compared with delaying accumulation until July 1 (3,320 pounds per acre), August 1 (2,870 pounds per acre), or September 1 (1,480 pounds per acre).
- Delaying the initiation date of accumulation at monthly intervals from June 1 to September 1 reduced DM yields linearly when the fescue was harvested in mid-November.
- The application of an additional 60 pounds of N per acre on July 1 increased the accumulated DM yields by mid-November in all 3 years, averaging 1,117 more pounds DM per acre. In previous studies, repeated heavy application of nitrogen in June and July resulted in appreciable increases in leaf diseases, dead tissue, and loss of stands. Therefore, the only additional nitrogen applied during this period was part of the treatments made on July 1. Also, more recent studies have shown that applications of

nitrogen on August 7 to 15 may be more effective in the piedmont than those made on the August 25 date chosen for the treatments in this study.

- The proportion of green tall fescue tissue in the summer-accumulated forage varied between 57% (year 2) and 66% (year 3). The lowest proportions occurred in the July 1 starting date when an additional 60 pounds of N were applied per acre (51% in year 2 and 50% in year 3), and the highest proportions occurred in the forage accumulated from September 1 (70% in year 2 and 77% in year 3).
- Green yield, preferred by grazing animals, varied considerably between year 2 and year 3 (not measured in year 1). Within year 2, the June 1, July 1, and August 1 accumulated forages had similar green yields averaging 1,623 pounds per acre by November 15. In year 3, the total green yields were higher for all treatments, with the June 1 and July 1 accumulated forages having similar yields that averaged 2,565 pounds per acre, whereas the August 1 green yields were lower at 1,920 pounds per acre. The September 1 accumulated forage had the highest proportion of green tissues in both years (< 70%). In year 2, green yields were lowest at only 510 pounds per acre for the September 1 forage, but in year 3 they were similar to the June 1, July 1, and August 1 green yields and averaged 2,290 pounds per acre.
- Repeated summer accumulation on the same land area over 4 years did not reduce DM yields and gave yields similar to those that would have been expected from land not previously used for summer accumulation.
- The proportion of weeds in accumulated tall fescue was not altered by starting date and averaged only 8% of the DM in year 2 and 3% in year 3.
- No carryover effect on subsequent spring harvests was noted after 4 years of repeating the summer accumulation treatment. In the fourth year, however, the application of 60 pounds of N per acre on July 1 resulted in greater DM yields for the April 21 harvest in the fifth spring and for the spring total that approached significance ($P = 0.06$ and 0.08, respectively).
- Considering the spring growth (through June 1) and fall growth (June 1 through mid-November), seasonal dry matter yields averaged from 6,050 to 8,460 pounds per acre.
- Summer-accumulated forage averaged 64.2% IVDMD by mid-November, ranging from 62.0% for the June 1 treatment to 71.1% for the September 1 treatment. Applying an additional 60 pounds of nitrogen at the start of accumulation on July 1 resulted in the lowest IVDMD, averaging 56.6%.
- Delaying the accumulation date from June 1 to September 1 increased IVDMD, averaging a 3.0 percentage unit increase for every 30-day delay.
- Forage from both the June 1 and July 1 accumulations had sufficient IVDMD to support only modest daily gains of either replacement heifers or steers that might be carried over the winter. The August 1 and September 1 accumulations, however, contained sufficient energy to provide acceptable daily performance for growing stock. All four accumulations had adequate IVDMD to support pregnant or average lactating brood cows.
- Crude protein concentrations were not altered by accumulation period, averaging 12.8% for the 3-year study. They varied by year with the lowest concentrations of 10.9% in year 2.
- Crude protein concentrations in the accumulated forage were generally adequate to support the daily ruminant response that could be supported from IVDMD concentrations.

Study 6. Changes in the Nutritive Value of Summer-Accumulated Tall Fescue During the Fall and Winter

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Situation

The relationship between summer accumulation of tall fescue and its yield potential when harvested in mid-November was discussed in Study 5. Of further importance, however, is the change in nutritive value of the accumulated forage during fall and winter. The dry matter digestibility and N concentrations of the accumulated forage determines, to a large extent, the type of daily animal response that can be expected or the type of supplementation that may be required to attain a specific daily animal response. The objective of this study was to determine the nutritive value of tall fescue accumulated from June 1, July 1, August 1, and September 1 when sampled monthly from October through March. Nitrogen application to all five treatments was delayed until August 25, although one of the five included an additional 60 pounds of N per acre on July 1.

Experimental Procedures

The experiment was conducted on Cecil clay loam soil at the Reedy Creek Road Field Laboratory near Raleigh, N.C. For details about the establishment of Kentucky 31 tall fescue on the site and subsequent cultural practices, see Study 5.

Treatments and Sampling

Five treatments were evaluated in a randomized complete block design with four replicates. The treatments consisted of four periods of forage accumulation beginning June 1, July 1, August 1, and September 1. The fifth treatment was a nitrogen rate variable with 60 pounds of N per acre applied July 1 (J+N) when accumulation was initiated. All five treatments were topdressed with 80 pounds of N per acre with ammonium nitrate on August 25. Previous experience had demonstrated that stand losses could occur when nitrogen was applied in June or July.

Each plot (6.2 feet by 15 feet) was halved (3.1 feet), and one-half was assigned randomly for yield estimates and harvested only in mid-November (see Study 5). The other half of the plot was designated for monthly samplings in October through March. Those results are presented here. The study was conducted for 3 years on a previously unused tall fescue stand. The plots assigned for nutritive value estimates were mapped into two rows of six subplots (total of 12 subplots), each 0.5 foot by 1.5 feet. The six subplots within each row were randomly assigned to six monthly sampling dates beginning October 15 and ending in early March. Forage from the appropriate two subplots was harvested by hand to a 2-inch stubble each month. The two subsamples then were composited. Approximately half was immediately quick frozen in liquid nitrogen then transferred to a freezer for storage. Thereafter, samples were freeze dried, ground in a Wiley mill to pass through a 1-mm screen, and returned to a freezer until analyzed. The other half of the sample was oven dried (160^{o}F), ground in a Wiley mill to pass through a 1.0-mm screen, and stored until analyzed.

In years 2 and 3, an additional stockpiled sample was harvested and hand separated into tall fescue and weeds. The tall fescue fraction was further separated into green and dead tissue (the green and dead tissue was separated for each leaf), then oven dried. The tall fescue tissue was ground in a Wiley mill to pass through a 1-mm screen and stored for analyses. The proportion of green and dead tissue was determined after subtracting the weight of the weeds.

Nutritive Value

Freeze-dried and oven-dried samples of the intact canopy and of the green and dead tissue were analyzed for in vitro dry matter disappearance (IVDMD) according to Burns and Cope (1974); neutral detergent fiber (NDF), acid detergent fiber (ADF), permanganate lignin, and neutral detergent ash were analyzed according to Goering and Van Soest (1971). Cellulose (CELL) was determined by subtracting lignin plus ash from ADF, and hemicellulose (HEMI) was determined by subtracting ADF from NDF. Total N was determined (AOAC, 1990) and multiplied by 6.25 and expressed as percent crude protein. Samples from selected treatments and sampling dates were analyzed for total nonstructural carbohydrates (TNC) and separated into starch, simple sugars, sucrose, and fructosans (Smith, 1969). A number of representative samples were selected from the oven-dried samples of the accumulated forage and analyzed. This permitted a comparison between the method of drying (freeze drying vs. oven drying) the accumulated forage on subsequent changes in nutritive value concentrations. Because the drying method frequently altered nutritive value constituents of the accumulated forage (Appendix Table 6.1), only analyses from freeze-dried samples of the whole canopy are presented. Oven drying combines amino acids and soluble sugars into a complex that has properties similar to lignin and is not representative of what animals would graze. Freeze drying leaves the tissue very close to the state of fresh forage.

Statistical Analyses

Data were statistically analyzed in combined analyses (over years) for a randomized complete block design. When treatments interacted with years, the analyses were conducted by year and the data were presented by year. The analysis of variance included a time trend (J+N treatment excluded) for length of accumulation [linear (L) and quadratic (Q)] and a N rate comparison for the July 1 initiation date (July 1 vs. J+N). A minimum significant difference (MSD) from the Waller-Duncan K ratio (K = 100) t-test (SAS Institute, 1985) also was determined and included for other comparisons of interest. A paired t-test was used to determine if nutrient concentrations differed between freeze-dried and oven-dried samples of the whole canopy (See Appendix Table 6.1).

Results and Discussion

The distribution of rainfall during the forage accumulation periods differed appreciably among the years (see Appendix Table 5.1). Average or above average rainfall in June or July and below average rainfall in August or September would favor forage accumulation from the early initiation dates, but may reduce the nutritive value of the accumulated forages.

The Stockpile

In vitro dry matter disappearance (IVDMD). The summer initiation dates of the accumulated forage influenced IVDMD at each sampling, showing an increase from June 1 to September 1 (Table 6.1). Adding an additional 60 pounds of N per acre on July 1 reduced the IVDMD at the October, November, and December samplings, but differences were not significant in January, February, or March.

The IVDMD declined between the December and January sampling, averaging an 8.8 percentage unit drop (range = 6.7 to 10.5 percentage units). This decline is attributed to frost injury and would greatly influence the type of livestock that could reasonably be sustained on this forage in midwinter. Replacement heifers and steers carried over the winter should make acceptable gains from August 1- and September 1-accumulated forages until January. Thereafter, daily gains may be less than desired without supplementation. Forage accumulated from June 1 and July 1 would support only modest daily gains of growing livestock. Tall fescue accumulated from August 1 and September 1 would meet the nutrient needs of the average lactating beef brood

Table 6.1. Changes in the in vitro dry matter disappearance of tall fescue from four summer accumulation dates. It was sampled from October to March (oven-dry basis).

	Sample date					
Item	**Oct. 15**	**Nov. 13**	**Dec. 10**	**Jan. 8**	**Feb. 5**	**Mar. 5**
	.... %					
Accumulation date[a]						
June 1	57.0	62.0	59.5	49.0	49.5	52.9
July 1 (J)	62.4	64.0	62.9	52.4	52.9	56.4
J+N[b]	56.3	56.6	56.5	49.7	49.3	52.3
Aug. 1	68.8	67.0	63.9	57.2	57.5	58.7
Sept. 1	71.7	71.1	69.9	60.0	61.2	62.3
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	0.04	< 0.01	0.01	NS[d]	NS	0.08
MSD[e]	5.7	3.8	3.9	3.9	4.7	4.7
Year[f]						
1	60.2	66.2	63.6	54.5	57.8	57.7
2	62.3	63.0	63.2	52.2	49.7	57.7
3	66.9	63.3	60.9	54.4	54.8	54.2
Significance						
MSD	NS	NS	NS	2.1	4.1	NS
Mean[g]	63.2	64.2	62.5	53.6	54.1	56.5
CV (%)[h]	6.5	4.3	4.2	5.0	5.9	3.5

[a] Values are the mean of 3 years and four replicates (n = 12).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear (J+N not included).
[d] NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Values are the mean of five treatments and four replicates (n = 20).
[g] Values are the mean of five treatments, 2 years, and four replicates (n = 40).
[h] CV = coefficient of variation.

cow during fall and winter, while the June 1, July 1, and J+N accumulations would be adequate only into early December. All summer accumulations would provide forage of adequate nutritive value for a mature cow through the midthird of pregnancy (NRC, 1984).

In the 3 years evaluated, IVDMD differed only for the January and February samplings. The differences were of little biological concern in January, but differences noted in February may be important. Because of the importance of IVDMD in determining the daily animal response that can be obtained from the various summer accumulations, the data for each of the three years are presented in Appendix Tables 6.2-6.4.

In assessing the nutritive value of the accumulated forage, it is also important to consider the DM yield accumulated for any specific starting date. As discussed in Study 5, yields were appreciably higher from the early summer accumulation dates than from the September 1 accumulation.

Crude protein (CP). The concentrations of CP in the accumulated forage were generally not altered by the initiation date at any of the sampling dates (Table 6.2). The one exception was January, when a decline was noted, and is attributed to the lower concentration of crude protein (9.6%) in the September 1-accumulated forage. In general, CP concentrations were adequate to support daily responses expected based on forage digestibility. Year 2, however, resulted in CP concentrations of the forage that may be limiting for higher daily responses (Table 6.2 and Appendix Table 6.5). Concentrations in October and November appear adequate for the energy in the forage, but a reduction in CP occurred after the November 13 sampling. By December 10, CP concentration had declined sufficiently to be inadequate for growing ruminants. The exception was the J+N treatment, which had adequate CP concentrations for growing animals. This shows an advantage in year 2 in favor of the additional 60 pound of N per acre applied at the July 1 accumulation date. Concentrations of CP recovered some in February and March, making them adequate for most growing animals. This same trend was noted for the September 1-accumulated forage in year 3 (Appendix Table 6.5).

Table 6.2. Changes in the crude protein concentration of tall fescue from four summer accumulation dates. It was sampled from October to March (oven-dry basis).

Item	Sample date						
	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	Mar. 5	Mean
	%						
Accumulation date[a]							
June 1	14.7	12.6	10.6	10.6	11.5	13.1	12.2
July 1 (J)	15.6	12.7	11.0	11.2	12.1	13.4	12.7
J+N[b]	15.2	13.2	11.6	12.5	13.3	13.7	13.3
Aug. 1	15.2	12.8	10.6	11.5	12.1	13.4	12.6
Sept. 1	16.2	12.8	11.3	9.6	11.0	14.0	12.5
Significance							
Trend[c]	NS	NS	NS	Q	NS	NS	NS
J vs J+N	NS	NS	NS	0.07	NS	NS	NS
MSD[d]	—	—	—	1.5	—	—	—
Year[e]							
1	17.5	14.8	13.1	14.0	15.9	19.7	15.8
2	12.8	10.9	9.1	9.5	10.2	10.5	10.5
3	15.8	12.8	10.8	9.8	9.9	10.4	11.6
Significance							
MSD	1.6	1.3	1.2	1.1	1.2	0.6	0.8
Mean[f]	15.4	12.8	11.0	11.1	12.0	13.5	12.6
CV (%)[g]	7.1	9.0	11.9	10.8	8.3	4.9	7.7

[a] Values are the mean of 3 years and three replicates (n = 9).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] NS = not significant and Q = quadratic response (J+N not included).
[d] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[e] Values are the mean of five treatments and three replicates (n = 15).
[f] Values are the mean of five treatments, 3 years, and three replicates (n = 45).
[g] CV = coefficient of variation.

Total nonstructural carbohydrates (TNC). The TNC ranged from a low of 10.3% in the J+N-accumulated forage to a high of 15.7% in the September 1 accumulation (Table 6.3). The TNC concentration changed little between the June 1 and August 1 accumulations, then increased in the less mature September 1 accumulation. This high level of TNC in the September forage is consistent with the higher IVDMD values noted in Table 6.1. The TNC concentrations in the summer-accumulated forages differed among years, with year 2 being highest at 14.8%. The sample dates data show that TNC increased from 9.9% on October 15 to 15.1% by December 10 (Table 6.3). The fructosan concentrations appeared to be the TNC constituent that was altered most to cause year and sampling date differences. Data are presented for each year separately in Appendix Table 6.6.

Fiber fractions. The amount of neutral detergent fiber in the summer-accumulated forage was influenced by the period of accumulation at each sampling date from October 15 to early March (Table 6.4). Concentrations averaged 52.3% in October and increased to about 62% in February and March. As the period of accumulation declined the NDF also declined, which is consistent with the increase in IVDMD noted in Table 6.1.

A major increase in NDF, averaging 7.2 percentage units, occurred between the December 10 and January 8 sampling. There was little difference in NDF among the accumulation treatments before December 10 or after January 8. The exception was the September 1 accumulation, which was generally significantly lower than the others. Adding additional nitrogen July 1 at the start of accumulation significantly increased NDF concentrations at only the October 15 and March 5 samplings, and is probably of little importance. The year and date of sampling showed differences in NDF concentration, but these were variable and probably weather dependent.

Acid detergent fiber concentrations reflect the changes noted for NDF and are presented in the Appendix Table 6.7 to provide information on these forages for use in dairy ration formulation. In addition, the hemicellulose and cellulose data were included for completeness (Appendix Tables 6.8 and 6.9).

Table 6.3. Total nonstructural carbohydrates (TNC) and constituent fractions of tall fescue from four summer accumulation dates. It was sampled in October and December (oven-dry basis).

Item	Carbohydrate fractions				
	TNC	Simple sugars	Sucrose	Fructosan	Starch
	%				
Accumulation date[a]					
June 1	12.3	2.8	3.3	5.8	0.4
July 1 (J)	11.8	2.8	3.5	5.0	0.5
J+N[b]	10.3	2.7	2.6	4.5	0.5
Aug. 1	12.4	2.8	3.3	5.6	0.7
Sept. 1	15.7	3.0	4.7	7.4	0.6
Significance:					
Trend[c]	Q	NS	L	Q	L
J vs. J+N	NS	NS	NS	NS	NS
MSD[d]	12	—	1.2	1.7	0.2
Year[e]					
1	11.7	1.5	4.4	5.5	0.5
2	14.8	3.7	3.3	7.3	0.5
3	10.9	3.3	2.8	4.1	0.6
Significance					
MSD	1.6	0.4	0.7	1.1	NS
Sample date[f]					
Oct. 15	9.9	2.0	3.1	4.0	0.8
Dec. 10	15.1	3.7	3.9	7.3	0.2
Significance	0.03	NS	NS	0.01	0.01
Mean[g]	12.5	2.8	3.5	5.7	0.5
CV (%)[h]	12.3	20.7	26.5	16.7	42.8

[a] Each value is the mean of 3 years, two sample dates and three replicates (n = 18).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear and Q = quadratic (J+N not included); NS = not significant.
[d] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[e] Each value is the mean of five treatments and two sample dates and three replicates (n = 30).
[f] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[g] Each value is the mean of five treatments, two sampling dates, 3 years, and three replicates (n = 90).
[h] CV = coefficient of variation.

Lignin concentrations ranged from an average of 3.8% at the October sampling to an average of 6.3% at the January and February samplings (Table 6.5). Lignin concentrations declined in the summer-accumulated forage as the date was delayed from June 1 until September 1. The August 1 and September 1 stockpiles had similar lignin concentration at all samplings, while the June 1 and J+N accumulation had higher concentrations. Year differences were only present at the October and February sampling. These differences were small and not considered of biological importance.

Proportion of green and dead tissue. In year 2, the proportion of the accumulated forage that was green tissue ranged from an average of 57% at the November sampling to an average of 26% at the February sampling (Table 6.6). In year 3, the green tissue averaged 77% in October and declined to 24% by March. At the fall sampling dates, the proportion of green tissue increased as the accumulation date was delayed. This difference was lost by February in year 2 and by December in year 3. The proportion of green tissue was only slightly lower in forage that received nitrogen on July 1 in year 2, except at the March sampling. In that case the lower percentage of green leaf in the J+N accumulation was attributed to a cool, late spring and slowness of new growth to begin in early March under the carryover forage. In year 3, the addition of nitrogen on July 1 resulted in lower percentages of green leaf at the October to the December samplings, after which the percentages of green leaf were similar.

The relationship between the proportion of dead tissue and IVDMD of the five accumulation treatments for all sampling dates is shown in Figure 6.1. The data for year 2 show that all accumulations, except for the September 1 initiation date, had similar changes in IVDMD as the dead proportion increased. For every 10 percentage unit increase in dead tissue, the IVDMD declined 5.4 percentage units as indicated in the regression equation in Figure 6.1. In the case of the September 1-accumulated forage, the decrease was less, averaging a 3.8 percentage unit decline in IVDMD for every 10 percentage unit increase in dead tissue. In year 3 the relationship was different. All summer accumula-

Table 6.4. Changes in the neutral detergent fiber concentration of tall fescue from four summer accumulation dates. It was sampled from October to March (oven-dry basis).

	Sample date					
Item	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	Mar. 5
	%					
Accumulation date[a]						
June 1	53.8	54.3	54.0	61.6	63.6	63.3
July 1 (J)[b]	53.0	52.3	53.5	60.6	62.4	61.6
J+N	56.0	55.1	56.1	62.3	64.0	63.7
Aug. 1	51.2	49.6	53.1	60.4	61.1	61.5
Sept. 1	47.5	46.3	49.7	57.7	59.4	59.6
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	0.06	NS[d]	NS	NS	NS	0.04
MSD[e]	3.2	3.8	3.5	2.2	2.8	2.1
Year[f]						
1	53.5	47.2	50.1	57.7	55.5	56.5
2	52.8	52.7	53.0	61.5	65.4	61.3
3	50.7	54.8	56.8	62.3	65.4	68.1
Significance						
MSD	2.0	4.7	2.3	0.7	1.2	1.2
Mean[g]	52.3	51.5	53.3	60.5	62.1	61.9
CV (%)[h]	2.9	5.1	3.1	2.3	2.0	2.0

[a] Each value is the mean of 3 years and three replicates (n = 9).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear (J+N not included).
[d] NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and three replicates (n = 15).
[g] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[h] CV = coefficient of variation.

Table 6.5. Changes in the lignin concentration of tall fescue from four summer accumulation dates. It was sampled from October to March (oven-dry basis).

Item	Sample date Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	Mar. 5
	....	....	%	....	....	....
Accumulation date[a]						
June 1	5.9	5.5	5.7	7.4	6.8	6.5
July 1 (J)	3.5	5.2	4.0	6.2	6.6	5.9
J+N[b]	4.3	6.0	5.0	7.5	7.5	6.3
Aug. 1	3.0	3.8	3.8	5.2	5.3	4.7
Sept. 1	2.4	4.3	3.6	5.0	5.2	5.4
Significance						
Trend[c]	Q	L	Q	L	L	L
J vs. J+N	NS[d]	NS	< 0.03	< 0.02	< 0.05	NS
MSD[e]	1.1	1.0	0.8	1.0	0.8	1.4
Year[f]						
1	4.0	4.6	4.0	6.6	6.4	5.5
2	4.0	5.1	4.4	6.3	6.8	5.6
3	3.4	5.2	4.9	2.9	5.6	6.2
Significance						
MSD	0.3	NS	NS	NS	0.7	NS
Mean[g]	3.8	5.0	4.4	6.3	6.3	5.7
CV (%)[h]	14.4	13.8	13.6	16.4	15.3	13.4

[a] Each value is the mean of 3 years and three replicates (n = 9).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear and Q = quadratic (J+N not included).
[d] NS = not significant.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and three replicates (n = 15).
[g] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[h] CV = coefficient of variation.

tions, except the J+N, showed the same relationship of a reduction in IVDMD of 2.6 percentage units for every 10 percentage unit increase in dead tissue. In the case of the J+N accumulation date, the IVDMD was reduced only 1.9 percentage units for every 10 percentage unit increase in dead tissue. These data suggest that the IVDMD of the dead tissue is not always consistent and can vary based on how the tissue died. In year 2, the dead tissue from the September 1 accumulation had higher IVDMD initially and throughout the fall-winter sampling. Tissue death in this case occurred mainly from frosting. In year 3 the J+N accumulation already had a high proportion of dead tissue by the October sampling, and IVDMD concentrations were relatively low to start with and changed less throughout the winter. In this case appreciable dead tissue developed during the summer accumulation period and was assumed to be a result of normal senescence (death from shading or maturation).

Figure 6.2 shows the general relationship between green and dead tissue and changes in the nutritive value constituents of the whole canopy specifically for the July 1 + N and August 1 accumulations from year 3. Year 3 was selected because the accumulated forages were free of green tissue in March, which is indicative of early spring growth.

Green and Dead Tissue

The green tissue averaged 72.4 and 70.3% IVDMD in the November, December, and February samplings taken in years 2 and 3 (Table 6.7). This was about 1.96 times higher than the 37.0% IVDMD for dead tissue in year 2 and 1.70 times higher than the 41.4% IVDMD for dead tissue in year 3. Summer accumulation beginning July 1, August 1, and September 1 did not alter the IVDMD of the green tissue at the November sampling in year 2 nor 3. But it was different in December in both years and in February of year 2 only. The green tissue from the December and February harvest should support acceptable gains of growing animals assuming IVDMD is approximately equal to total digestible nutrients (TDN) and if intake was not limiting (NRC, 1984).

Table 6.6. Changes in the proportion of green tissue in tall fescue from four summer accumulation dates. Fescue from each starting date was sampled from October or November to March (oven-dry basis).

	Year 2					Year 3					
Accumulation date	**Nov. 13**	**Dec. 10**	**Jan. 8**	**Feb. 6**	**Mar. 5**	**Oct. 15**	**Nov. 12**	**Dec. 10**	**Jan. 8**	**Feb. 4**	**Mar. 3**
	%										
June 1	54[a]	43	35	26	37	71	67	57	38	23	23
July 1 (J)	55	47	35	26	39	78	67	57	37	22	25
J+N[b]	51	46	34	24	34	66	50	44	30	24	22
Aug. 1	56	48	38	27	39	81	71	61	39	26	27
Sept. 1	70	54	41	27	41	87	77	62	42	32	25
Significance											
Trend[c]	Q	L	L	NS	NS	L	L	NS	NS	NS	NS
J vs. J+N	NS	NS	NS	NS	< 0.01	< 0.01	< 0.01	< 0.01	NS	NS	NS
MSD[d]	7	7	5	—	4	8	6	7	—	8	—
Mean[e]	57	48	37	26	38	77	66	56	37	25	24
CV (%)[f]	8.2	8.7	7.7	13.0	6.1	6.8	6.5	8.2	15.1	18.1	27.3

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] Q = quadratic and L = linear (J+N not included); NS = not significant.
[d] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[e] Each value is the mean of five treatments and four replicates (n = 20).
[f] CV = coefficient of variation.

Although the dead tissue was low in IVDMD, it was also altered by summer accumulation date (Table 6.7). The major difference was the low IVDMD from the J+N stockpile vs. the other two. The dead tissue generally would not be adequate to support even a pregnant brood cow, although IVDMD concentrations in the September 1 forage did approach the total digestible nutrients requirement of 48.8% (NRC, 1984).

The crude protein concentration of the green and dead tissue was not altered by the summer accumulation date or by applying additional N at the July 1 starting date. The concentration in the green tissue averaged 12.5, 10.9, 11.5, and 12.3 for the November 13, December 10, January 8, and February 5 samplings. Respective crude protein concentrations for the dead tissues were 9.8, 9.1, 9.7, and 9.2% (data not shown).

The concentration of total nonstructural carbohydrates that were determined in the August 1-accumulated forage increased from 11.1% at the November sampling to 20.0% by December before declining to 15.7% in January and 14.7% by February (Table 6.8). This reduction is probably of biological importance as it represents a decline in the daily intake of readily available energy. All four constituents of TNC increased between November and December, and these accumulated increases resulted in the high TNC concentration noted at the December 10 sampling. Dead tissue TNC concentrations were extremely low, averaging only 2.1% compared with 15.4% for green tissue. Although concentrations were low, dead tissue reflected the same trend noted for the green tissue. The TNC concentration was highest at the December 10 sampling, averaging 3.4%, then decreased to 1.4% by February. Such low TNC concentrations in the dead tissue contribute, in part, to the low IVDMD reported for dead tissue in Table 6.7.

The NDF of the green tissue averaged 49.2% and was altered by the summer accumulation date (Table 6.9). The September 1 accumulation had the lowest

Table 6.7. Changes in the in vitro dry matter disappearance of green and dead tissue of tall fescue from three summer accumulation dates. It was sampled in November to February, years 2 and 3 (oven-dry basis).

	Green tissue			Dead tissue		
Item	**Nov.**	**Dec.**	**Feb.**	**Nov.**	**Dec.**	**Feb.**
	.... %					
	Year 2					
Accumulation date						
July 1+N[a]	67.0[b]	72.3	71.9	31.8	35.0	26.1
Aug. 1	64.1	74.6	73.1	41.1	37.4	27.9
Sept. 1	67.9	81.6	79.7	45.9	41.0	46.5
Significance						
MSD[c]	NS	4.3	3.6	8.2	4.6	0.9
Mean[d]	66.3	76.2	74.9	39.6	37.8	33.5
CV (%)[e]	4.6	3.2	2.8	11.8	7.1	1.7
	Year 3					
Accumulation date						
July 1+N	64.1	67.5	73.9	29.2	28.0	39.8
Aug. 1	66.7	70.1	76.2	45.0	44.9	44.1
Sept. 1	65.9	73.6	74.7	47.6	49.7	44.2
Significance						
MSD	NS	28	NS	4.2	5.2	NS
Mean	65.6	70.4	74.9	40.6	40.9	42.7
CV (%)	2.4	2.3	5.3	6.1	7.6	8.1

[a] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[b] Each value is the mean of four replicates.
[c] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test; NS = not significant.
[d] Each value is the mean of three treatments and four replicates (n = 12).
[e] CV = coefficient of variation.

concentration at 47.5%, which was similar to that of the August 1 accumulation but lower than that of July 1. The other fiber fraction (ADF, HEMI, and CELL) showed similar responses. The lignin concentration was similar for all accumulated forages. In the 2 years that sampling occurred, all fiber fractions concentrations were higher in year 3 than in year 2. The exception was HEMI, which had similar concentration in both years.

The dead tissue averaged 70.0% NDF or about 42% greater than the concentration in green tissue (Table 6.9). This difference was also noted for the other fiber fractions, with the dead tissue concentrations being 58% higher in ADF, 27% higher in HEMI, 43% higher in CELL, and 187% higher in lignin than in the green tissue (Table 6.9). These higher fiber concentrations were associated with the loss of soluble constituents as nonstructural carbohydrates, organic acids, and nitrogen. These all contributed to the low IVDMD reported for dead tissue in Table 6.7. None of the fiber fractions of the dead tissue were altered by the length of summer accumulation, by the date of sampling (December or February), or by the year of sampling.

Plotting the changes in nutritive value constituents for the green and dead tissue from the August 1-accumulated forage sampled in year 3 (accumulation not altered by early spring growth) shows appreciable consistency within the green and within the dead tissue fractions from November through March (Figure 6.2).

Importance of green tissue. The green tissue from the July 1 + N, August 1, and September 1-accumulated forages was consistently high in IVDMD, averaging 70% or higher from December through February. If these tissues could be consumed as the sole diet, and assuming IVDMD was approximately equal to TDN and intake was not limiting, they could support adequate daily gains for replacement heifers, for carrying over steers, or for pregnant, superior lactating brood cows (NRC, 1984).

As noted in Figure 6.1, the relationship between the dead tissue and IVDMD is negative; IVDMD declines as the proportion of dead tissue in the canopy increases. Figure 6.2 shows the relationship

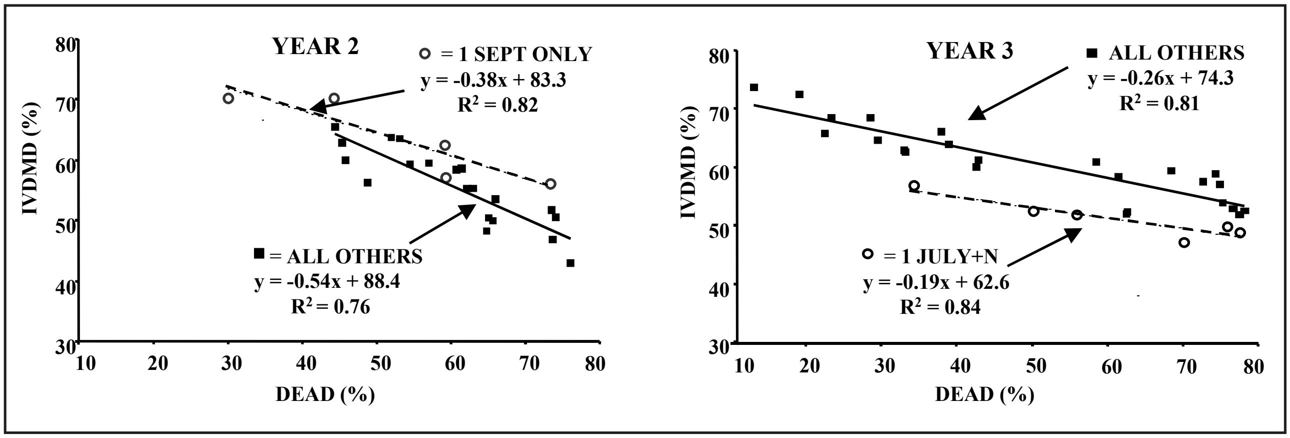

Figure 6.1. Relationship between in vitro dry matter disappearance and the percentage of dead tissue in summer-accumulated tall fescue, years 2 and 3. Data represent the accumulation dates of June 1, July 1, July 1 + 60 pounds of N per acre, August 1, and September 1, as well as five fall-winter sampling dates in year 2 and six in year 3. Each value is the mean of four replicates.

between green tissue and dead tissue and associated changes in IVDMD and other nutritive value measurements from October to March. Figure 6.3 makes clear that the IVDMD and other nutritive value constituents of the summer-accumulated forages remain rather consistent within the green tissue as well as consistent within the dead tissue during the fall-winter period. This indicates that the reduction in the nutritive value of the summer-accumulated forages as the winter progresses is mainly attributed to the increasing proportion of dead tissue over time.

The dead tissue results from either normal senescence during the summer accumulation period or from frosting. The tissue that dies normally appears to be lower in nutritive value than the tissue that dies after a frost. It is well established that grazing ruminants will select green leaf if the opportunity exists. In accumulated forage, however, the extent to which preferential selection can occur becomes limited as green and dead tissue are generally present together on a common leaf, or pseudo stem.

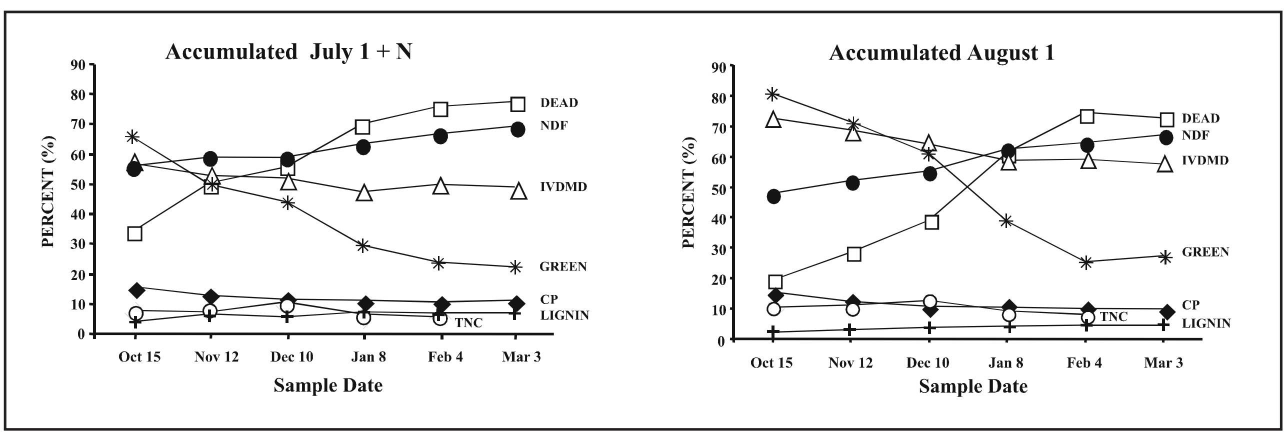

Figure 6.2. Changes from October to March in the proportion of green (✳) and dead (□) tissue, as well as changes in in vitro dry matter disappearance (△), crude protein (◆), total nonstructural carbohydrates (○), neutral detergent fiber (•), and lignin (+) concentrations in tall fescue accumulated from July 1 (and topdressed with an additional 60 pounds of N per acre) and from August 1 in year 3. The associated standard errors (SE) were 4.4% for green tissue, 2.9% for IVDMD, 1.0% for CP, 1.3% for TNC, 1.6% for NDF, and 0.8% for lignin.

Table 6.8. Changes in the total and constituent nonstructural carbohydrate concentrations of green and dead tall fescue accumulated from August 1. It was sampled in November to February (oven-dry basis).

Item	Simple sugars	Sucrose	Fructosan	Starch	Total
	Nonstructural carbohydrate fractions				
	%				
	Green tissue				
Sample date[a]					
November	0.6	2.7	7.6	0.2	11.1
December	1.2	6.7	11.8	0.4	20.0
January	1.5	4.1	9.6	0.2	15.7
February	0.8	6.0	7.7	0.2	14.7
Significance MSD[b]	NS	3.7	NS	NS	8.9
Year[c]					
2	1.1	4.4	10.8	0.3	16.7
3	0.9	5.3	7.5	0.2	14.1
Significance	NS	0.03	NS	NS	NS
Mean[d]	1.0	4.9	9.2	0.3	15.4
CV (%)[e]	61.3	20.7	18.3	50.1	12.0
	Dead tissue				
Sample date[a]					
November	0.2	0.5	1.1	0.4	2.2
December	0.6	1.4	1.2	0.3	3.4
January	0.3	0.4	0.6	0.3	1.5
February	0.2	0.4	0.5	0.3	1.4
Significance MSD[b]	0.1	0.5	0.4	NS	1.1
Year[c]					
2	0.2	0.6	0.8	0.3	2.0
3	0.4	0.7	0.9	0.3	2.3
Significance	0.07	NS	NS	NS	NS
Mean[d]	0.3	0.7	0.8	0.3	2.1
CV (%)[e]	29.4	39.4	33.7	39.8	26.9

[a] Each value is the mean of 2 years and three replicates (n = 6).
[b] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[c] Each value is the mean of four sample dates and three replicates (n = 12).
[d] Each value is the mean of 2 years, four sampling dates, and three replicates (n= 24).
[e] CV = coefficient of variation.

Summary and Conclusions

Tall fescue can be accumulated during the summer and managed so its nutritive value will be adequate for meeting the nutrient requirements of both growing and lactating beef cattle as late as March.

- The time of summer accumulation altered the nutritive value at every sampling date from October to March. Accumulation dates from June and July resulted in lowest IVDMD, averaging 56.7%.
- The highest nutritive value occurred from a September 1 starting date with IVDMD averaging 66.0% in samples taken in October to March. But that value was not statistically different from the 62.2% average obtained from the August 1 accumulation. Further, the August 1 accumulation averaged nearly double the dry matter yield (2,866 vs. 1,477 pounds per acre).
- Applying an additional 60 pounds of N per acre on July 1 vs. adding none on that starting date reduced IVDMD of the accumulated forage in October, November, and December (56.5 vs. 63.1%), but IVDMD was similar from January to March (50.4 vs. 53.9%).
- A large decline in IVDMD, averaging 8.8 percentage units, occurred between the December 10 and January 8 samplings. This has important implications when relatively high daily performance is expected from animals grazing the accumulated forage.
- Crude protein concentrations were generally not altered during the fall and winter period by changes in the summer accumulation date but declined as the winter progressed. Concentrations for the study averaged 12.6% (range = 11.0 to 15.4%), but large differences by year were noted. Crude protein averaged 15.8% in year 1 (range = 12.1 to 21.3%), 10.5% in year 2 (range = 7.8 to 13.5%), and 11.6% in year 3 (range = 8.8 to 16.6%). Concentrations in year 2 were frequently borderline for growing stock.
- The proportion of green tissue among the summer accumulations differed until December or January, with the September 1 accumulation consistently having the highest proportion and the July 1 + N usually having the least.
- A 10 percentage unit increase in dead tissue (reduction in green tissue) resulted in a 3.8 percentage unit decline in IVDMD in year 2 and a 2.6 percentage unit decline in year 3.

Table 6.9. Concentrations of neutral detergent fiber (NDF), acid detergent fiber (ADF), hemicellulose (HEMI), cellulose (CELL), and lignin in tall fescue from three summer accumulation dates. It was sampled in December and February, years 2 and 3 (oven-dry basis).

	Fiber fractions				
Item	**NDF**	**ADF**	**HEMI**	**CELL**	**Lignin**
	.... %				
	Green tissue				
Accumulation date[a]					
July 1 (J)	50.0	25.1	24.9	21.8	2.4
J+N[b]	50.3	25.5	24.9	22.2	2.4
Aug. 1	48.9	24.6	24.3	21.4	2.3
Sept. 1	47.5	23.7	23.7	20.6	2.3
Significance					
MSD[c]	1.7	1.4	0.6	1.2	NS
Year[d]					
2	48.2	23.8	24.4	20.8	2.1
3	50.1	25.6	24.5	22.3	2.6
Significance	0.01	< 0.01	NS	< 0.01	< 0.01
Mean[e]	49.2	24.7	24.4	21.5	2.3
CV(%)[f]	3.3	4.1	3.3	4.3	7.3
	Dead tissue				
Mean[e]	70.0	39.1	30.9	30.7	6.6
CV (%)[f]	1.3	1.9	2.6	2.7	6.1

[a] Each value is the mean of two sample dates (December and February), 2 years and three replicates (n = 2).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[d] Each value is the mean of four treatments, two sample dates (December and February), and three replicates (n = 24).
[e] Each value is the mean of four treatments, two sample dates (December and February), 2 years, and three replicates (n = 48).
[f] CV = coefficient of variation.

- The nutritive value of green tissue was high and changed little from November to February, averaging 72.4% IVDMD in year 2 and 70.3% in year 3.
- The nutritive value of dead tissue was low and changed little from November to February, averaging 37.0% IVDMD in year 2 and 41.4% in year 3.
- The proportion of green to dead tissue in the stockpile appears to be the major factor in determining the nutritive value.

The data presented here and in Study 5 indicate several management strategies for using summer-accumulated tall fescue over the fall and winter. For example, producers with wintering ruminants that have high energy requirements (such as steers and replacement heifers) could initiate the stockpile in

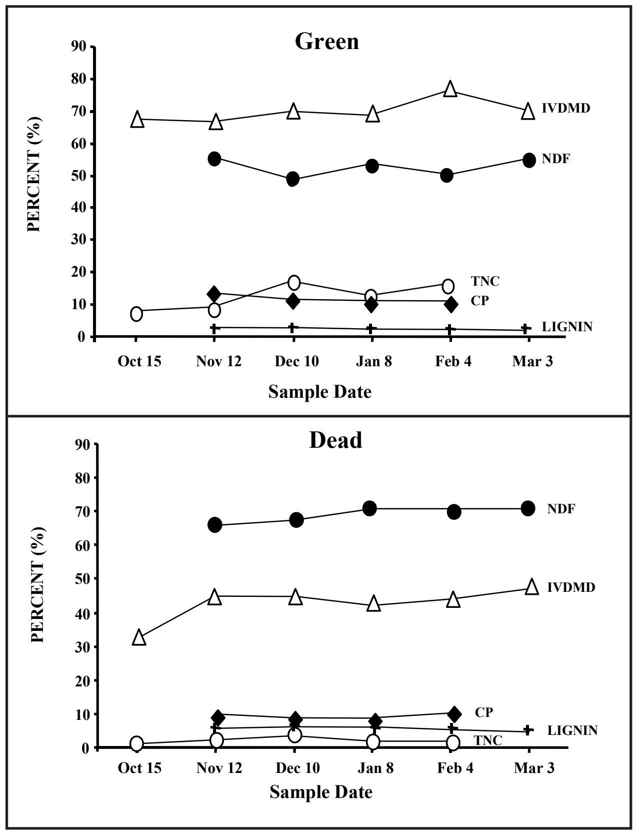

Figure 6.3. Changes from October to March in in vitro dry matter disappearance (△), crude protein (◆), total nonstructural carbohydrates (○), neutral detergent fiber (•), and lignin (+) concentrations of green and dead tall fescue tissue accumulated from August 1 in year 3. The associated standard errors (SE) were 3.2% for IVDMD, 1.3% for CP, 0.6% for TNC, 0.8% for NDF, and 0.3% for lignin.

August or by September 1 to minimize the amount of dead tissue that normally occurs during accumulation. This strategy will generally reduce the dry matter yield of the accumulated forage (see Study 5) but will provide higher nutritive value. Utilization of the accumulated forage by late December should provide acceptable forage for growing ruminants. If DM yield is of major concern, producers could use earlier initiation dates, such as June or July 1. Also, a moderate N application (< 70 pounds per acre) at the start of summer accumulation would maximize DM production. However, N application in June or July should not exceed 50 pounds per acre and should be applied in split application in both months to avoid possible stand losses. For maximum efficiency, growing stock could have first access to the green tissue, and then the brood cows could clean up any rejected forage.

In another management strategy, producers could initiate summer accumulation on a portion of their land in June or July to maximize yield production and use this forage only for wintering of brood cows. Accumulation on the remaining portion of the land could be delayed until August or September 1, and that accumulated forage could be utilized for growing out young stock.

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Appendix

Appendix Table 4.1. Long-term mean rainfall and temperature reported by month with yearly departures from recordings taken about 1.2 miles from the experimental site.[a]

			Departures					
	Long-term mean		Year 1		Year 2		Year 3	
Month	**Rainfall**	**Temp.**	**Rainfall**	**Temp.**	**Rainfall**	**Temp.**	**Rainfall**	**Temp.**
	in.	°F	in.	°F	in.	°F	in.	°F
Jan.	3.35	41.6	-1.67	-4.2	-0.96	-8.7	0.06	-4.6
Feb.	3.71	43.1	0.37	-2.1	0.24	-4.1	0.62	-0.9
March	3.67	50.4	0.60	-6.1	-1.69	-3.3	0.34	-4.4
April	3.34	59.4	-2.09	-0.6	-0.45	0.1	-0.93	-2.9
May	3.81	68.1	-0.67	-1.4	-0.16	-1.6	1.16	-3.2
June	4.22	75.4	1.11	-0.4	-2.83	-2.4	-0.91	0.3
July	5.44	78.3	-1.09	0.1	0.15	-1.8	-0.93	-1.3
Aug.	5.32	77.1	1.11	-3.1	-0.73	-1.6	1.06	-1.6
Sept.	3.70	71.7	2.36	-3.7	-2.65	2.1	-0.94	0.8
Oct.	2.93	61.0	-0.62	-1.9	1.76	0.5	4.82	4.3
Nov.	2.53	50.7	-1.76	-3.9	-1.18	-0.6	-0.96	-1.3
Dec.	3.21	42.8	0.29	-4.2	-0.45	0.8	-1.33	8.4

[a] Data recorded at the Raleigh-Durham International Airport by the National Oceanic and Atmospheric Administration.

Appendix Table 4.2. Annual dry matter yields, nitrogen removal, and seasonal mean growth rates of tall fescue from eight defoliation treatments (oven-dry basis).

Treatment[a]	Dry matter yield[b]			Nitrogen[c]			Growth rate[d]		
	Yr 1	Yr 2	Yr 3	Yr 1	Yr 2	Yr 3	Yr 1	Yr 2	Yr 3
inches	.... lb/acre			.... lb/acre			.... lb/acre/day		
1. 3-1.5	3,720	2,820	5,400	—	—	—	21.6	17.7	23.6
2. 3-2	4,090	3,570	5,700	—	—	—	23.5	19.5	25.9
3. 4-2	4,200	3,460	5,850	132	98	187	26.6	20.7	29.4
4. 6-2	4,780	4,200	6,540	143	110	203	21.6	22.8	29.0
5. 12-2	5,080	6,310	7,990	—	—	—	20.3	17.0	31.3
6. 4.5-3.5	3,620	3,170	4,380	112	88	142	20.1	17.5	21.3
7. 6-3.5	3,420	3,360	4,520	—	—	—	19.3	17.7	21.9
8. 12-3.5	4,550	5,780	7,140	123	132	192	16.8	13.3	29.9
Meaningful comparisons (probability)									
C_1 (1 vs. 2)	<0.01	<0.01	0.13	—	—	—	0.03	0.17	0.07
C_2 (3,4,5 vs. 6,7,8)	<0.01	<0.01	<0.01	<0.01	0.19	0.03	<0.01	<0.01	<0.01
C_3 (5 vs. 3,4)	<0.01	<0.01	<0.01	—	—	—	<0.01	<0.01	0.05
C_4 (3 vs. 4)	<0.01	<0.01	<0.01	0.04	0.17	0.32	<0.01	0.01	0.75
C_5 (8 vs. 6,7)	<0.01	<0.01	<0.01	0.02	<0.01	0.02	<0.01	<0.01	<0.01
C_6 (6 vs. 7)	0.09	0.43	0.49	—	—	—	0.35	0.90	0.62
C_7 (2 vs. 3,4,5)	<0.01	<0.01	<0.01	—	—	—	0.32	0.54	<0.01
MSD[e]	220	440	360	10	18	39	1.6	2.5	2.3
Mean	4,180	4,080	5,940	128	107	181	21.2	18.3	26.5
CV (%)	3.9	8.2	4.6	3.8	8.1	10.4	5.7	9.8	6.3

[a] Treatment designations represent plant growth defoliated to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates totaled for three to 22 harvests.
[c] Each value is the mean of three replicates determined by multiplying total N and dry matter yield at each harvest and summed for three to 22 harvests depending on treatment and year.
[d] Growth rates represent the quantity of dry matter harvested divided by the calendar days since the previous harvest. The growth rate is the average for two to 22 harvests depending on year and treatment. The rate for the initial harvest in each treatment was not included.
[e] MSD = minimum significant difference based on the Waller-Duncan k-ratio (k = 100) t-test.

Appendix

Appendix Table 4.3. Seasonal mean in vitro dry matter disappearance (IVDMD), digestible dry matter, and associated nutritive value of tall fescue from eight defoliation treatments (oven-dry basis).

		Digestible dry matter			Fiber fractions[a]				
Item	**IVDMD**	**Year 1**	**Year 2**	**Year 3**	**NDF**	**ADF**	**HEMI**	**CELL**	**Lignin**
	%	.... lb/acre			.... %				
Defoliation treatments[b] (inches)									
1. 3-1.5	73.3[c]	2,730[d]	2,050[d]	3,980[d]	43.3[c]	24.2[c]	19.1[c]	19.4[c]	3.7[c]
2. 3-2	74.2	3,040	2,630	4,240	44.4	24.4	19.9	20.6	3.1
3. 4-2	74.3	3,170	2,520	4,360	44.4	24.6	19.9	20.6	3.1
4. 6-2	71.4	3,530	2,910	4,650	46.7	26.0	20.7	21.6	3.6
5. 12-2	69.3	3,680	4,300	5,380	51.1	28.0	23.1	23.6	3.7
6. 4.5-3.5	74.1	2,690	2,330	3,260	45.3	24.9	20.5	21.3	2.9
7. 6-3.5	72.7	2,580	2,380	3,250	46.2	25.6	20.6	22.0	3.0
8. 12-3.5	67.9	3,290	3,750	4,750	50.3	28.1	22.3	23.8	3.6
Meaningful comparisons (probability)									
C_1 (1 vs. 2)	0.50	< 0.01	< 0.01	0.05	0.43	0.70	0.28	0.05	< 0.01
C_2 (3,4,5 vs. 6,7,8)	0.91	< 0.01	< 0.01	< 0.01	0.85	0.96	0.76	0.23	0.02
C_3 (5 vs. 3,4)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.06
C_4 (3 vs. 4)	0.04	< 0.01	0.03	0.03	0.09	0.03	0.24	0.07	0.03
C_5 (8 vs. 6,7)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.01	< 0.01	< 0.01
C_6 (6 vs. 7)	0.32	0.26	0.75	0.93	0.52	0.24	0.90	0.21	0.57
C_7 (2 vs. 3,4,5)	0.03	< 0.01	< 0.01	< 0.01	0.01	< 0.01	0.04	< 0.01	0.02
MSD[e]	—[f]	180	310	240	—	—	—	—	—
Year									
1	73.9	—	—	—	46.3	26.0	20.3	21.6	3.6
2	70.7	—	—	—	48.3	26.8	21.4	22.5	3.5
3	71.8	—	—	—	44.9	24.4	20.5	20.6	3.0
MSD	1.6	—	—	—	0.3	0.2	0.3	0.2	0.2
Mean	72.1	3,090	2,860	4,230	46.5	25.7	20.7	21.6	3.3
CV (%)	1.2	4.4	8.2	4.2	1.5	1.8	3.5	2.1	4.7

[a] NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; and CELL = cellulose.
[b] Treatment designations represent plant growth defoliated to a specific stubble; for example, 3-1.5 designates that each time tall fescue attained 3 inches, it was cut back to a 1.5-inch stubble.
[c] Each value is the mean of four replicates and 3 years weighted for individual harvest within each year (n = 12).
[d] Each value is the mean of four replicates totaled for three to 22 harvests depending on treatment and year (n = 4).
[e] MSD = minimum significant difference based on the Waller-Duncan k-ratio (k = 100) t-test.
[f] — indicates that the MSD was not calculated.

Appendix Table 4.4. Seasonal mean concentrations of crude protein (CP), water-soluble carbohydrates (WSC), and minerals of tall fescue from four defoliation treatments (oven-dry basis).

Item	CP	WSC	Minerals			
			P	K	Ca	Mg
	%	%	.... %	....		
Defoliation treatments[a] (inches)[b]						
1. 4-2	19.2	12.6	0.41	2.63	0.46	0.29
2. 6-2	18.3	12.2	0.37	2.56	0.48	0.29
3. 4.5-3.5	19.3	12.9	0.41	2.71	0.40	0.27
4. 12-3.5	16.2	11.9	0.34	2.49	0.40	0.28
Significance	<0.01	0.26	0.15	0.11	0.04	0.26
Meaningful comparisons (probability)						
C_1 1 vs. 2	0.19	—[c]	—	—	0.46	—
C_2 3 vs. 4	<0.01	—	—	—	0.94	—
C_3 1 vs. 3	0.77	—	—	—	0.07	—
Years[d]						
1	18.5	13.9	3.9	2.65	0.49	0.27
2	16.9	10.5	3.6	2.52	0.42	0.28
3	19.3	12.8	3.9	2.61	0.41	0.31
MSD[e]	0.5	0.3	0.01	0.10	0.04	0.02
Mean	18.2	12.4	0.38	2.59	0.44	0.28
CV (%)	3.7	3.2	3.6	2.7	5.3	2.9

[a] Treatment designations represent plant growth defoliated to a specific stubble; for example, 4-2 designates that each time tall fescue growth attained 4 inches it was cut back to a 2-inch stubble.

[b] Each value is the mean of four replicates for WSC and three replicates for all other variables over 3 years. The values were weighted for individual harvest within years, which ranged from 3 to 22 depending on treatment and year (n = 12 or 9).

[c] — designates that treatments were not significantly different.

[d] Each value is the mean of four treatments and four replicates for WSC and three replicates for all other variables (n = 16 or 12).

[e] MSD = minimum significant difference, based on the Waller-Duncan k-ratio (k = 100) t-test.

Appendix

Appendix Table 4.5. Number of calendar days between each harvest.

Treatment	No. regrowth intervals																					
	1[a]	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
inches																						
Year 1																						
3-1.5	58	12	10	28	18	15	42	15	37	7												
3-2	58	5	7	7	28	10	11	15	42	15	37	7	7									
4-2	58	5	7	10	25	21	15	42	15	37	7											
6-2	70	38	18	57	52	14																
12-2	73	53	72	37																		
4.5-3.5	58	5	7	3	4	28	10	11	15	42	15	37	7	7								
6-3.5	58	5	7	7	28	10	11	15	42	15	37	7	7									
12-3.5	73	53	57	52																		
Year 2																						
3-1.5	55	9	15	12	65	19	15	15	55	8												
3-2	55	9	8	7	12	20	45	19	9	13	41	22	8	8								
4-2	55	9	15	12	65	19	15	15	55	8												
6-2	72	19	93	76	8																	
12-2	84	113	97																			
4.5-3.5	55	9	8	7	12	8	12	45	19	9	13	41	22	8	8							
6-3.5	64	15	20	85	13	63	8															
12-3.5	84	106	104																			
Year 3																						
3-1.5	49	9	10	11	12	7	14	16	45	18	10	25	14	7	12	9						
3-2	49	9	8	13	12	7	14	16	45	18	10	25	14	7	12	9	14					
4-2	49	9	8	12	13	12	13	16	62	19	25	14	7	12	9							
6-2	58	21	19	84	27	31	19	22														
12-2	82	38	89	59																		
4.5-3.5	49	9	7	7	7	12	7	6	9	7	8	45	9	9	10	8	17	14	7	12	9	13
6-3.5	58	21	12	13	16	53	9	9	18	31	19	9										
12-3.5	82	38	89	28	31																	

[a] Growth of tall fescue was assumed to begin on February 10 to determine the calendar days in the first harvest interval.

Appendix Table 4.6. Dry matter yield, mean daily growth rate, in vitro dry matter disappearance and estimated digestible dry matter yields, and nutrient concentrations for tall fescue from a range of cutting heights during the growing season, year 1 (oven-dry basis).

	April					May			June		July	August		October		
Treatment[a]	**9**	**14**	**21**	**24**	**28**	**1**	**26**	**29**	**5**	**16**	**1**	**12**	**27**	**3**	**10**	**17**
inches																
Dry matter (lb/acre)[b]																
3-1.5	341		597			256		439		388	176	553	239	541	184	
3-2	341	215	335		160		515		115	195	167	640	229	769	322	89
4-2	451	222	335			208	402			391	194	649	252	716	377	
6-2			1,298					713		393		842		1,087		441
12-2				1,875						1,433			1,067	701		
4.5-3.5	243	158	309	85	48		421		142	209	155	519	209	871	144	111
6-3.5	293	164	331		131		361		144	188	152	521	193	705	135	98
12-3.5				1,861						926		693		1,074		
Mean growth rate (lb/acre/day)[b,c]																
3-1.5	6		50			26		16		22	12	13	16	15	26	
3-2	6	43	48		23		18		11	18	11	15	15	21	46	13
4-2	8	44	48			21	16			19	13	15	17	19	54	
6-2			19					19		22		15		21		31
12-2				26						27			15	19		
4.5-3.5	4	31	44	28	12		15		14	21	10	12	14	23	21	16
6-3.5	6	37	47		18		13		14	17	10	12	13	19	19	14
12-3.5				25						17		12		21		
In vitro dry matter disappearance (%)[b]																
3-1.5	81.1		77.7			76.3		65.3		68.9	68.8	69.1	72.4	78.9	76.7	
3-2	81.5	81.5	77.8		75.9		67.4		68.5	71.2	70.1	68.7	72.5	78.2	77.3	78.4
4-2	81.5	79.1	79.5			78.0	67.7			71.1	69.3	71.1	72.4	79.6	77.6	
6-2			80.5					64.7		73.2		66.6		76.8		77.2
12-2			80.5	78.9						66.3			66.0	77.2		
4.5-3.5	81.7	78.8	79.3	77.7	74.4		66.4		68.5	70.0	69.0	69.3	73.3	76.7	81.5	79.0
6-3.5	81.8	79.6	78.3		75.7		68.3		68.5	70.9	69.7	70.2	72.5	81.5	80.0	79.7
12-3.5				75.5						63.9		66.1		78.2		

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates.
[c] See Appendix Table 4.5 for calendar days between harvest dates for each treatment. Growth rates reported are simply yield at harvest divided by days in growth interval.

Appendix Table 4.6 (continued). Dry matter yield, mean daily growth rate, in vitro dry matter disappearance and estimated digestible dry matter yields, and nutrient concentrations for tall fescue from a range of cutting heights during the growing season, year 1 (oven-dry basis).

	April					May			June		July	August		October		
Treatment[a]	**9**	**14**	**21**	**24**	**28**	**1**	**26**	**29**	**5**	**16**	**1**	**12**	**27**	**3**	**10**	**17**
inches																
Digestible dry matter (lb/acre)[b]																
3-1.5	276		464			195		286		267	121	381	173	427	141	
3-2	278	175	260		121		346		79	139	117	442	166	601	250	70
4-2	368	177	266			162	272			278	135	463	182	570	293	
6-2			1,045					461		288		561		835		341
12-2				1,478						950			703	544		
4.5-3.5	198	125	246	66	35		280		98	146	107	359	152	670	117	88
6-3.5	239	130	258		99		246		99	133	106	365	139	577	108	78
12-3.5				1,405						592		459		839		
Crude protein (%)[c d]																
4-2	22.0	22.5	20.0			18.5	14.0			16.0	15.3	16.1	18.4	24.4	21.7	
6-2			21.5					13.4		14.9		14.2		22.9		20.3
4.5-3.5	22.3	22.6	21.1	18.5	21.0		13.3		15.3	15.9	15.7	15.2	18.0	22.8	21.5	21.6
12-3.5				17.1						13.6		14.7		22.7		
Water-soluble carbohydrates (%)[c d]																
4-2	16.5	13.3	16.7			12.5	11.4			11.5	9.7	13.7	16.5	12.9	17.1	
6-2			17.3					10.6		11.9		12.9		12.9		15.4
4.5-3.5	15.6	14.5	18.6	17.7	12.7		10.9		11.0	10.3	10.7	13.4	18.2	12.5	17.0	16.5
12-3.5				18.7						9.7		11.3		11.5		

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates.
[c] See Appendix Table 4.5 for calendar days between harvest dates for each treatment. Growth rates reported are simply yield at harvest divided by days in growth interval.
[d] Each value is the mean of three replicates.

Appendix Table 4.7. Dry matter yield, mean daily growth rate, and digestible dry matter yield for tall fescue from a range of cutting heights during the growing season, year 2 (oven-dry basis).

	April				May			June	July	Aug.				Sept.	Oct.		Nov.		Dec.
Treatment[a]	6	15	23	30	5	12	20	1	16	3	13	19	26	3	6	28	5	13	1
inches																			
Dry matter (lb/acre)[b]																			
3-1.5	342	377		433		323			249	251		257		143		346	93		
3-2	440	154	219	287		411		226	164	334	363		207		236	336	135	59	
4-2	241	152		647		393			319	429		373		181		577	148		
6-2			993			880					1,256					917	156		
12-2					2,685							2,340							1,281
4.5-3.5	342	229	221	175		305	119	73	89	333	451		193		246	244	100	54	
6-3.5		686		491			399				954		243			463	129		
12-3.5					2,978							2,128							671
Mean growth rate (lb/acre/day)[c]																			
3-1.5	6	42		29		27			4	13		17		9		6	12		
3-2	8	17	27	41		34		11	4	18	40		16		6	15	17	7	
4-2	4	17		43		33			5	23		25		12		11	19		
6-2			14			46					13					12	19		
12-2					32								21						13
4.5-3.5	6	25	28	25		25	15	6	2	17	50		15		6	11	12	7	
6-3.5		11		33			20				11		19			7	16		
12-3.5					35							20							7
Digestible dry matter (lb/acre)[c]																			
3-1.5	283	299		325		231			144	169				91		260	74		
3-2	365	129	164	212		299		149	104	234	255		139		160	263	109	48	
4-2	198	125		486		288			188	301		259		124		434	122		
6-2			740			635					785					624	124		
12-2					1,877								1,411						1,012
4.5-3.5	283	192	167	129		224	82	47	50	231	319		129		160	187	83	44	
6-3.5		541		357			270				603		166			339	105		
12-3.5					1,977							1,251							518

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates.
[c] See Appendix Table 4.5 for calendar days between harvest dates for each treatment. Growth rates reported are simply yield at harvest divided by days in growth interval.

Appendix Table 4.8. In vitro dry matter disappearance, crude protein, and water-soluble carbohydrate concentrations of tall fescue from a range of cutting heights during the growing season, year 2 (oven-dry basis).

	April				May			June	July	Aug.				Sept.	Oct.		Nov.		Dec.
Treatment[a]	**6**	**15**	**23**	**30**	**5**	**12**	**20**	**1**	**16**	**3**	**13**	**19**	**26**	**3**	**6**	**28**	**5**	**13**	**1**
inches																			
In vitro dry matter disappearance (%)[b]																			
3-1.5	83.3	79.5		74.3		71.5			57.4	67.3		68.3		63.5		75.1	79.0		
3-2	83.2	83.9	74.9	74.1		73.0		65.8	63.4	70.1	69.4		67.5		68.1	78.3	81.1	81.4	
4-2	82.6	81.9		75.1		73.4			58.6	70.1		69.5		68.8		75.4	82.3		
6-2			74.7			72.1					62.6					68.2	79.7		
12-2					69.7								60.5						79.1
4.5-3.5	83.1	83.7	75.7	72.6		73.5	69.4	65.0	57.1	69.4	71.5	71.5	67.2		65.3	76.9	83.9	81.3	
6-3.5		79.2		72.8			67.8				63.4		68.5			73.1	81.1		
12-3.5					66.3							58.8							77.2
Crude protein (%)[c]																			
4-2	17.1	17.9		18.8		19.2			12.6	17.9		15.5		17.6		20.8	21.7		
6-2			15.5			17.2					15.6					19.2	21.5		
4.5-3.5	18.0	18.6	19.0	19.6		19.0	17.2	16.4	13.5	17.3	16.6		17.1		16.7	20.7	20.7	21.2	
12-3.5					14.7							13.6							15.0
Water-soluble carbohydrates (%)[c]																			
4-2	18.1	13.3		9.1		9.6			7.2	9.3		9.5		7.7		13.1	15.7		
6-2			11.7			9.4					8.3					11.1	15.7		
4.5-3.5	17.8	14.5	11.2	8.7		9.6	8.7	8.6	7.9	8.4	10.5		8.3		11.9	14.1	17.5	14.7	
12-3.5					8.3							7.4							20.3

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.

[b] Each value is the mean of four replicates.

[c] Each value is the mean of three replicates.

Appendix Table 4.9. Dry matter yield, mean growth rate, and digestible dry matter yield for tall fescue from a range of cutting heights during the growing season, year 3 (oven-dry basis).

Treat-	Mar.	April					May				June			August				Sept.		October				Nov.	
ment[a]	31	9	16	19	23	30	3	12	19	25	3	10	18	2	11	20	30	7	24	5	8	15	27	5	18
inches																									
Dry matter (lb/acre)[b]																									
3-1.5	714	375		329		388		588	216		337		266	528		146	150		757		167	118	186	132	
3-2	543	357	282			507		620	300		328		255	467		327	188		435		373	192	275	170	81
4-2	619	371	417			392		627		476		373			689		452		477		339	189	267	166	
6-2		1,061				998			1,015						1,358			647			639		503		322
12-2							2,820					1,651						1,626						1,890	
4.5-3.5	180	197	167		153	200		399	319	214	168	111	89	206	190	198	201	94	287		331	169	252	164	103
6-3.5		392				627		347		481		285		445	177	177		254			715		450	165	
12-3.5							2,067					1,851						1,691		747				785	
Mean growth rate (lb/acre/day)[c]																									
3-1.5	15	42		33		35		49	31		24		17	12		8	15		30		12	17	15	15	
3-2	11	40	35			39		52	43		23		16	10		18	19		17		27	27	23	19	6
4-2	13	41	52			30		52		37		23			11		24		19		24	27	22	18	
6-2		18				47			53						16			24			21		27	15	
12-2							34					43						18						32	
4.5-3.5	4	22	24		22	29		33	46	36	19	16	11	5	21	22	20	12	17		24	24	21	18	7
6-3.5		7				30		29		37		18		8	20	20		14			23		24	18	
12-3.5							25					49						19		27				25	
Digestible dry matter (lb/acre)[c]																									
3-1.5	611	317		268		297		436	151		225		168	323		101	105		514		124	91	138	107	
3-2	460	301	237			382		454	210		223		167	282		227	133		307		289	148	215	141	65
4-2	527	315	343			298		471		330		247			440		312		328		257	148	205	134	
6-2		868				768			714						742			448			457		390		261
12-2							2,094					1,045						898						1,345	
4.5-3.5	155	165	138		126	150		291	225	146	116	74	58	129	129	141	145	69	207		259	135	195	131	74
6-3.5		320				489		255		331		184		268	124	122		177			507		340	129	
12-3.5							1,526					1,126						945		550				604	

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates.
[c] Each value is the mean of three replicates.

Appendix Table 4.10. In vitro dry matter disappearance, crude protein, and water-soluble carbohydrate concentrations of tall fescue from a range of cutting heights during the growing season, year 3 (oven-dry basis).

Treat-ment[a]	Mar.	April					May				June			August				Sept.		October				Nov.	
	31	9	16	19	23	30	3	12	19	25	3	10	18	2	11	20	30	7	24	5	8	15	27	5	18
inches																									
In vitro dry matter disappearance (%)[b]																									
3-1.5	85.7	84.6		81.9		76.5		74.4	69.9		66.7		63.3	61.3		68.6	69.0		67.9		74.3	76.8	74.4	81.4	
3-2	84.9	84.4	84.0			75.5		73.2	69.9		68.1		65.7	60.5		69.6	70.6		70.3		77.3	77.4	78.5	82.7	79.9
4-2	85.3	84.9	82.3			76.2		75.3		69.5		66.3			63.6		68.9		68.8		76.0	78.0	76.8	80.9	
6-2		81.8				76.9			70.3						54.6			69.1			71.7		77.8		80.9
12-2							74.3					63.3						55.3						71.3	
4.5-3.5	85.5	83.7	83.1		82.3	75.1		73.4	70.7	69.3	69.0	66.5	65.6	63.1	67.8	70.9	71.8	72.9	72.0		78.0	79.7	77.8	79.8	80.7
6-3.5		81.6				78.0		73.3		68.8		64.9		60.3	70.3	69.0		69.7			70.8		75.7	77.7	
12-3.5							73.9					61.0						55.7		73.9				77.3	
Crude protein (%)[c]																									
4-2	24.4	23.6	23.6			24.0		18.2		18.6		17.3			15.2		17.0		16.1		21.0	25.3	25.2	24.4	
6-2		23.0				22.8			18.4						13.7			15.6			21.1		26.0		17.8
4.5-3.5	24.4	24.3	24.0		23.0	24.1		22.0	20.4	17.9	19.0	18.3	17.1	15.5	18.1	17.2	17.6	17.3	18.2		22.3	24.8	26.1	23.3	19.0
12-3.5							19.5						15.2					12.5		20.7				20.5	
Water-soluble carbohydrates (%)[c]																									
4-2	18.8	18.2	15.1			9.9		10.4		7.1		9.3			10.7		12.1		12.6		17.7	14.0	11.8	24.4	
6-2		14.9				11.3			10.1							8.7		11.9			14.7		12.1		27.5
4.5-3.5	19.5	17.3	17.3		16.7	10.0		9.4	10.7	7.6	8.3	9.5	8.2	10.1	12.9	12.2	12.7	13.3	13.4		17.4	14.5	11.3	22.7	27.2
12-3.5							12.2					9.7						9.4		15.9				22.6	

[a] Treatment designations represent plant growth cut to a specific stubble; for example, 3-1.5 designates that each time tall fescue growth attained 3 inches, it was cut back to a 1.5-inch stubble.
[b] Each value is the mean of four replicates.
[c] Each value is the mean of three replicates.

Appendix Table 5.1. Long-term mean rainfall and temperature reported by month with yearly departures from recordings taken about 1.2 miles from the experimental site.[a]

			Departures							
	Long-term means		Year 1		Year 2		Year 3		Year 4	
Month	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.
	in.	F°	in.	F°	in.	F°	in.	F°	in.	F°
May	3.8	68	0.5	-3.1	4.4	0.0	0.5	0.8	1.4	-0.6
June	4.3	75	5.7	0.0	0.4	-2.6	-2.0	-0.7	-1.1	0.3
July	5.4	78	-2.4	-1.4	-3.5	-1.0	1.7	-1.9	-4.1	1.1
Aug.	5.3	77	-0.6	-0.3	-0.1	-0.5	-2.8	1.8	-3.4	-1.1
Sept.	3.7	72	-2.7	2.0	-0.1	-1.6	2.0	0.5	2.2	-0.9
Oct.	2.9	61	-2.1	1.7	-1.6	-3.7	-1.6	2.0	1.2	-4.5
Nov.	2.6	51	-2.2	4.6	-1.0	-1.3	1.8	3.5	-0.9	-7.5
Dec.	3.3	43	3.4	0.6	0.9	2.0	1.0	0.8	1.0	-4.1
Jan.	3.3	42	1.2	8.8	2.9	3.3	-0.2	-2.9	-0.4	-13.9
Feb.	3.7	43	-0.5	0.7	-0.5	1.5	-1.8	7.9	-1.2	-2.9
March	3.7	50	-0.1	5.2	2.8	-2.1	-0.3	7.0	2.2	4.1
April	3.3	59	-1.8	0.7	-1.4	-3.7	-2.8	1.2	-1.2	3.1

[a]Data recorded at the Raleigh-Durham International Airport by the National Oceanic and Atmospheric Administration.

Appendix

Appendix Table 5.2. Mean initial dry matter yields harvested in mid-November from experimental areas 2 and 3 and repeated summer accumulation yields harvested in mid-November from the same areas (oven-dry basis).

Accumulation date	Area 2			Area 3	
		Repeated			Repeated
	Initial year	Year 2	Year 3	Initial year	Year 2
	...... lb/acre			...... lb/acre	
June 1	3,630[a]	3,490	2,980	4,040	3,400
July 1 (J)	3,090	3,490	2,370	3,760	2,600
J+N[b]	4,040	4,970	4,250	4,980	4,700
Aug. 1	3,120	3,070	2,390	2,870	2,180
Sept. 1	760	2,610	1,560	2,770	1,660
Significance					
Trend[c]	Q	L	L	L	L
J vs. J+N	<0.01	<0.01	<0.01	<0.01	<0.01
MSD[d]	510	430	470	440	640
Mean[e]	2,930	3,530	2,710	3,680	2,910
CV (%)[f]	12.2	8.6	12.3	8.4	15.3

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds applied to all treatments on August 25.
[c] L = linear and Q = quadratic (J+N not included).
[d] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[e] Each value is the mean of five treatments and four replicates (n = 20).
[f] CV = coefficient of variation.

Appendix Table 5.3. The influence of the previous summer's accumulation from four accumulation dates on subsequent spring dry matter yield from experimental area 2 (oven-dry basis).

Accumulation date	Spring, year 3				Spring, year 4			Spring, year 5			
	Apr. 10	May 7	June 2	Total	April 20	June 1	Total	Apr. 21	May 22	June 22	Total
	lb/acre				lb/acre			lb/acre			
June 1	740[a]	940	210	1,890	1,450	970	2,420	2,690	580	190	3,460
July 1 (J)	740	970	200	1,910	1,580	1,180	2,760	2,880	600	180	3,650
J+N[b]	830	1,110	250	2,190	1,560	1,120	2,690	3,170	630	240	4,050
Aug. 1	850	1,050	260	2,150	1,600	1,110	2,710	2,970	600	190	3,770
Sept. 1	760	1,030	160	1,950	1,580	1,090	2,670	2,930	570	160	3,660
Significance											
Treatment	0.47	0.35	0.08	0.37	0.59	0.05	0.08	0.04	0.61	0.19	0.07
MSD[c]	—	—	90	—	—	140	280	310	—	—	450
Mean[d]	780	1,020	220	2,020	1,560	1,090	2,650	2,930	590	190	3,720
CV (%)[e]	12.9	12.1	22.5	13.0	8.9	7.5	5.9	6.3	9.9	24.3	6.9

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds applied to all treatments on August 25.
[c] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[d] Each value is the mean of five treatments and four replicates (n = 20).
[e] CV = coefficient of variation.

Appendix Table 5.4. The influence of the previous summer's accumulation from four accumulation dates on subsequent spring dry matter yield from experimental area 3 (oven-dry basis).

Accumulation date	Spring, year 4			Spring, year 5			
	Apr. 20	June 1	Total	Apr. 21	May 23	June 22	Total
	.... lb/acre			.... lb/acre			
June 1	1,370[a]	1,090	2,450	2,770	620	220	3,600
July 1 (J)	1,400	1,120	2,520	2,540	680	250	3,470
J+N[b]	1,330	1,230	2,560	3,330	700	300	4,320
Aug. 1	1,450	1,130	2,580	2,920	620	200	3,740
Sept. 1	1,660	1,190	2,850	3,120	680	250	4,050
Significance							
Treatment	0.12	0.84	0.55	0.14	0.20	0.33	0.14
MSD[c]	—	—	—	—	—	—	—
Mean[d]	1,440	1,150	2,590	2,940	660	240	3,830
CV (%)[e]	12.1	16.4	13.2	14.0	8.5	27.3	12.4

[a] Each value is the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds applied to all treatments on August 25.
[c] MSD = minimum significant difference from the Waller-Duncan K ratio (K = 100) t-test.
[d] Each value is the mean of five treatments and four replicates (n = 20).
[e] CV = coefficient of variation.

Appendix Table 6.1. The influence of drying method on in vitro dry matter disappearance (IVDMD), crude protein, fiber fractions, and nonstructural carbohydrate concentrations from July 1- and August 1-accumulated tall fescue. It was sampled from October to March.

		Sample date																	
	No. of obser-	Oct. 15			Nov. 13			Dec. 10			Jan. 8			Feb. 5			March 5		
Item (%)	vations[a]	OD[b]	FD[b]	Sig. [c]	OD	FD	Sig.	OD	FD	Sig.	OD	FD	Sig.	OD	FD	Sig.	OD	FD	Sig.
IVDMD	24	59.4	62.3	<0.01	61.9	61.8	0.87	59.6	60.2	0.44	51.2	53.4	<0.01	51.3	53.4	<0.01	54.2	55.5	0.02
Crude protein	18	14.1	15.2	0.03	12.8	13.0	0.61	11.5	11.1	0.46	11.6	12.0	0.09	13.4	12.7	0.29	13.6	13.6	0.64
NDF[d]	18	56.2	53.6	<0.01	53.1	52.4	0.19	54.6	54.6	0.96	61.9	61.3	0.41	63.1	62.6	0.37	62.0	62.6	0.35
ADF	18	29.4	28.3	<0.01	28.8	30.5	0.01	29.5	28.9	0.14	33.2	33.7	0.36	34.2	35.0	0.17	32.6	34.9	<0.01
CELL	18	23.6	23.8	0.18	23.4	24.6	0.04	23.8	23.4	0.24	25.6	26.1	0.12	26.2	27.1	0.03	25.9	27.9	<0.01
HEMI	18	26.8	25.3	<0.01	24.3	21.9	<0.01	25.1	25.7	0.07	28.7	27.6	<0.01	28.9	27.6	0.13	29.4	27.7	0.03
Lignin	18	5.1	3.6	<0.01	4.7	4.9	0.16	4.7	4.4	0.07	6.4	6.4	0.93	6.7	6.4	0.22	5.2	5.5	0.19
TNC[e]	6	8.1	11.2	<0.01				10.5	14.6	<0.01				5.2	7.3	<0.01			
Simple sugars	6	0.93	2.15	0.10				0.74	4.91	<0.01				0.41	1.62	<0.01			
Sucrose	6	1.83	3.46	0.03				3.86	2.11	0.03				2.01	2.14	0.72			
Fructosan	6	4.18	4.55	0.40				5.59	7.03	0.09				2.60	3.22	0.03			
Starch	6	1.17	1.01	0.62				0.27	0.59	0.04				0.20	0.36	0.37			
Reducing sugars	6							1.23	5.66	<0.01									
Fructose	6							0.87	3.43	<0.01									
Glucose	6							0.35	2.23	<0.01									
Galactose	6							0.17	0.44	<0.01									

[a] 24 consists of two treatments (July 1+60 N and Aug. 1), 3 years, and four replicates; 18 consists of the same but only three replicates; and 6 consists of 2 years and three replicates for the August 1 accumulation date.

[b] OD = oven-dried at 165°F and FD = freeze-dried.

[c] Sig. = significance based on a 't' test of the difference between paired comparisons.

[d] NDF = neutral detergent fiber and constituent fractions, ADF = acid detergent fiber, CELL = cellulose, and HEMI = hemicellulose.

[e] TNC = total nonstructural carbohydrates.

Appendix Table 6.2. Changes in the in vitro dry matter disappearance of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March, year 1 (oven-dry basis).

Accumulation date	Sample date					
	Oct. 16	Nov. 13	Dec. 11	Jan. 8	Feb. 5	March 5
	%					
June 1	50.2[a]	63.0	58.7	46.6	49.5	50.5
July 1 (J)	58.8	66.2	63.8	54.3	55.3	56.5
J + N[b]	57.6	60.8	58.3	50.3	54.7	54.5
Aug. 1	61.8	66.7	63.9	57.7	61.6	59.8
Sept. 1	72.6	74.2	73.1	62.0	67.8	67.1
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	NS[d]	<0.01	0.01	0.05	NS	NS
MSD[e]	4.8	3.3	3.8	3.7	5.3	3.5
Mean[f]	60.2	66.2	63.6	54.2	57.8	57.1
CV (%)[g]	5.5	3.5	4.1	4.7	6.2	4.1

[a] Values are the means of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear response (J+N not included).
[d] NS = not significantly different.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and four replicates (n = 20).
[g] CV = coefficient of variation.

Appendix Table 6.3. Changes in the in vitro dry matter disappearance of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March, year 2 (oven-dry basis).

Accumulation date	Sample date					
	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 6	March 5
	%					
June 1	56.0[a]	60.0	59.4	48.2	46.9	55.2
July 1 (J)	62.4	62.9	63.5	50.4	50.6	58.6
J + N[b]	58.3	56.3	59.3	49.9	42.9	53.5
Aug. 1	66.1	65.6	63.6	55.2	51.8	58.7
Sept. 1	68.8	70.3	70.3	57.1	56.2	62.5
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	0.03	<0.01	0.04	NS[d]	<0.01	<0.01
MSD[e]	3.6	4.3	4.0	4.3	4.7	2.6
Mean[f]	62.3	63.0	63.2	52.2	49.7	57.7
CV (%)[g]	3.9	4.6	4.2	5.4	6.2	3.1

[a] Values are the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear response (J+N not included).
[d] NS = not significantly different.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and four replicates (n = 20).
[g] CV = coefficient of variation.

Appendix Table 6.4. Changes in the in vitro dry matter disappearance of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March, year 3 (oven-dry basis).

Accumulation date	Sample date					
	Oct. 15	Nov. 12	Dec. 10	Jan. 8	Feb. 4	March 3
	%					
June 1	64.8[a]	63.1	60.3	52.2	52.1	53.1
July 1 (J)	66.0	62.9	61.4	52.6	52.8	54.1
J + N[b]	57.1	52.8	52.1	47.4	50.1	49.1
Aug. 1	72.7	68.7	64.2	58.7	59.2	57.7
Sept. 1	73.9	68.8	66.4	61.1	59.8	57.3
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	<0.01	<0.01	<0.01	0.01	NS[d]	<0.01
MSD[e]	4.4	4.3	3.7	3.8	4.2	2.6
Mean[f]	66.9	63.3	60.9	54.4	54.8	54.2
CV (%)[g]	4.5	4.7	4.1	4.8	5.1	3.3

[a] Values are the mean of four replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear response (J + N not included).
[d] NS = not significantly different.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and four replicates (n = 20).
[g] CV = coefficient of variation.

Appendix Table 6.5. Changes in the crude protein concentration of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March (oven-dry basis).

Accumulation date	Sample date					
	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	March 5
	%					
Year 1						
June 1	16.0[a]	14.8	13.3	13.7	14.4	19.1
July 1 (J)	18.2	14.7	13.4	13.8	16.2	19.3
J+N[b]	16.4	14.3	12.3	14.8	16.0	18.1
Aug. 1	17.9	15.1	12.2	15.4	16.9	20.5
Sept. 1	19.1	15.0	14.1	12.1	16.0	21.3
Mean	17.5	14.8	13.1	14.0	15.9	19.7
Year 2						
June 1	12.5	10.6	8.7	9.3	10.2	10.2
July 1 (J)	13.2	10.5	8.4	10.0	10.1	10.8
J+N[b]	13.5	12.2	10.9	11.7	13.0	11.7
Aug. 1	12.0	10.6	8.9	8.7	9.4	9.6
Sept. 1	12.8	10.4	8.7	7.8	8.1	10.0
Mean	12.8	10.9	9.1	9.5	10.2	10.5
Year 3						
June 1	15.6	12.5	10.0	8.8	9.9	10.0
July 1 (J)	15.3	13.0	11.2	9.9	9.9	10.1
J+N[b]	15.8	13.0	11.5	11.1	10.9	11.2
Aug. 1	15.6	12.5	10.6	10.5	10.1	10.2
Sept. 1	16.6	13.1	11.2	8.9	8.9	10.7
Mean	15.8	12.8	10.8	9.8	9.9	10.4

[a] Values are the mean of three replicates.

[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.

Appendix Table 6.6. Changes in the total nonstructural carbohydrates (TNC) of summer-accumulated tall fescue from four accumulation dates. It was sampled in October and December (oven-dry basis).

Accumulation date	October 15			December 10		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
	.... %			.... %		
June 1	8.1[a]	10.0	8.7	12.7	18.5	15.7
July 1 (J)	7.7	10.9	8.5	14.8	18.6	10.0
J + N[b]	7.2	9.5	7.9	11.5	15.0	10.7
Aug. 1	8.9	12.0	10.4	12.7	16.6	12.7
Sept. 1	12.2	15.5	10.5	21.6	20.9	14.5
Significance						
MSD[c]	2.4	2.7	2.1	2.6	4.4	3.6
Mean[d]	8.8	11.6	9.2	15.0	17.9	12.6
CV (%)[e]	14.2	12.0	11.2	9.8	11.9	14.2

[a] Each value is the mean of three replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[d] Each value is the mean of five treatments and four replicates (n = 20).
[e] CV = coefficient of variation.

Appendix Table 6.7. Changes in the acid detergent fiber concentration of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March (oven-dry basis).

	Sample date					
Item	**Oct. 15**	**Nov. 13**	**Dec. 10**	**Jan. 8**	**Feb. 5**	**March 5**
	%					
Accumulation date						
June 1	31.0[a]	31.3	30.6	34.3	35.9	36.2
July 1 (J)	27.7	31.6	28.7	33.5	35.2	35.0
J + N[b]	29.9	32.7	30.1	35.1	36.2	35.7
Aug. 1	26.8	28.3	27.7	32.3	33.7	34.2
Sept. 1	31.0	27.3	25.6	30.8	33.3	33.3
Significance						
Trend[c]	L	L	L	L	L	L
J vs. J+N	<0.02	NS[d]	NS	NS	NS	NS
MSD[e]	1.6	1.6	2.5	3.3	1.7	1.4
Year						
1	27.1[f]	29.1	25.7	30.8	31.9	33.4
2	28.7	30.1	28.8	34.3	36.4	34.0
3	27.9	31.7	31.2	34.4	36.3	37.4
Significance						
MSD	0.8	2.3	2.1	1.6	3.9	1.4
Mean[g]	27.9	30.3	28.6	33.2	34.9	34.9
CV (%)[h]	3.7	4.8	3.9	5.6	4.0	3.7

[a] Each value is the mean of 3 years and three replicates (n = 9).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear (J+N not included).
[d] NS = not significantly different.
[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[f] Each value is the mean of five treatments and three replicates (n = 15).
[g] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[h] CV = coefficient of variation.

Appendix

Appendix Table 6.8. Changes in the hemicellulose concentrations of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March (oven-dry basis).

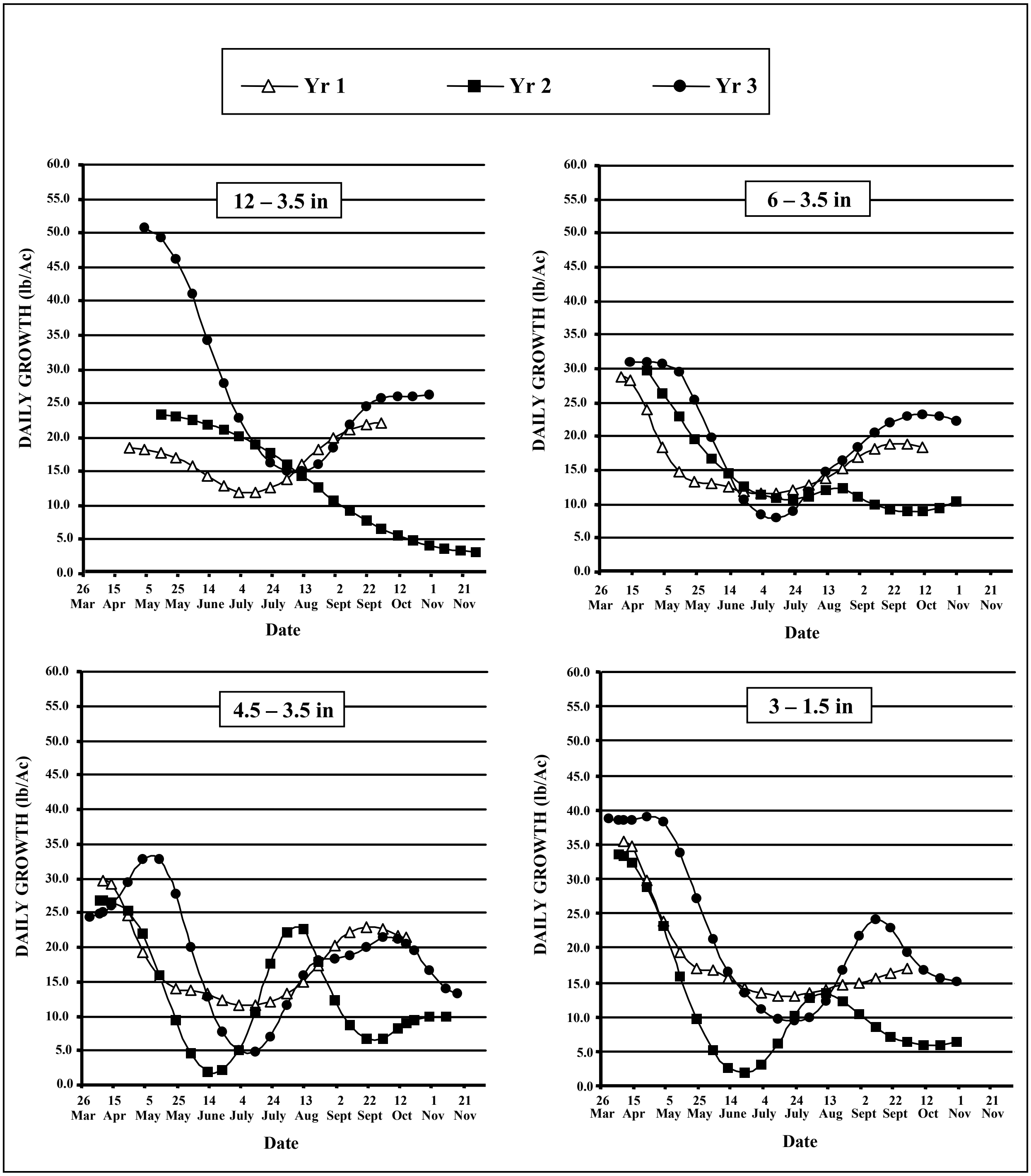
Item	Sample date					
	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	March 5
	%					
Accumulation date						
June 1	22.8[a]	23.0	23.4	27.3	27.7	27.1
July 1 (J)	25.2	20.7	24.9	27.1	27.1	26.6
J + N[b]	26.2	22.5	26.0	27.3	27.8	28.0
Aug. 1	24.4	21.3	25.4	28.0	27.4	27.3
Sept. 1	23.4	19.0	24.0	26.9	26.1	26.3
Significance						
Trend[c]	Q	L	Q	NS	NS	NS
J vs. J+N	NS	NS	0.07	NS	NS	NS
MSD[d]	2.3	3.6	1.3	—	—	—
Year						
1	26.4[e]	18.1	24.4	26.8	23.6	23.1
2	24.0	22.6	24.2	27.2	29.0	27.4
3	22.8	23.1	25.6	27.9	29.1	30.7
Significance						
MSD	1.6	NS	NS	NS	3.0	1.8
Mean[f]	24.4	21.3	24.7	27.3	27.2	27.1
CV (%)[g]	5.0	9.5	3.5	5.4	4.8	5.5

[a] Each value is the mean of 3 years and three replicates (n = 9).
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear, Q = quadratic (J+N not included); NS = not significantly different.
[d] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[e] Each value is the mean of five treatments and three replicates (n = 15).
[f] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[g] CV = coefficient of variation.

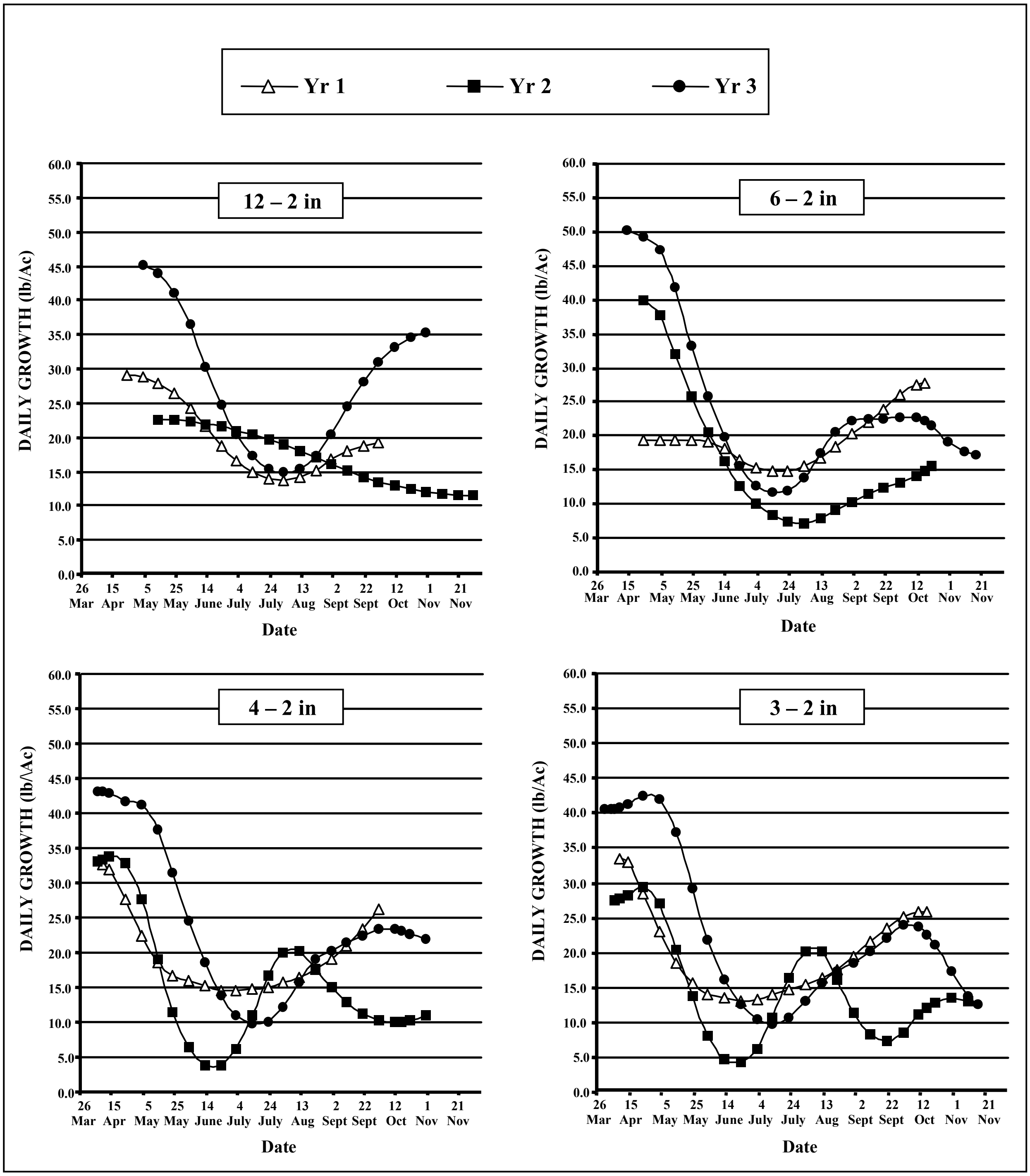
Appendix Table 6.9. Changes in the cellulose concentrations of summer-accumulated tall fescue from four accumulation dates. It was sampled from October to March (oven-dry basis).

Item	Sample date					
	Oct. 15	Nov. 13	Dec. 10	Jan. 8	Feb. 5	March 5
	%					
Accumulation date						
June 1	24.1[a]	24.7	23.9	26.7	27.6	28.3
July 1 (J)	23.4	25.4	23.5	26.1	27.1	27.4
J + N[b]	24.7	25.7	24.0	26.3	27.3	27.9
Aug. 1	22.9	23.5	22.8	26.0	27.0	28.0
Sept. 1	20.9	24.7	20.8	24.5	32.0	26.2
Significance						
Trend[c]	L	Q	L	L	NS	Q
J vs. J+N	<0.06	NS	NS	NS	NS	<0.06
MSD[d]	1.4	1.3	2.0	1.9	—	5
Year						
1	22.4[e]	23.3	21.0	23.4	24.4	23.1
2	23.6	23.9	23.0	26.4	31.1	27.4
3	23.6	25.6	25.1	28.0	29.2	30.7
Significance						
MSD	0.7	1.2	1.1	0.7	NS	1.8
Mean[f]	23.2	24.3	23.0	25.9	28.2	27.6
CV (%)[g]	2.8	3.7	3.2	3.0	25.8	4.0

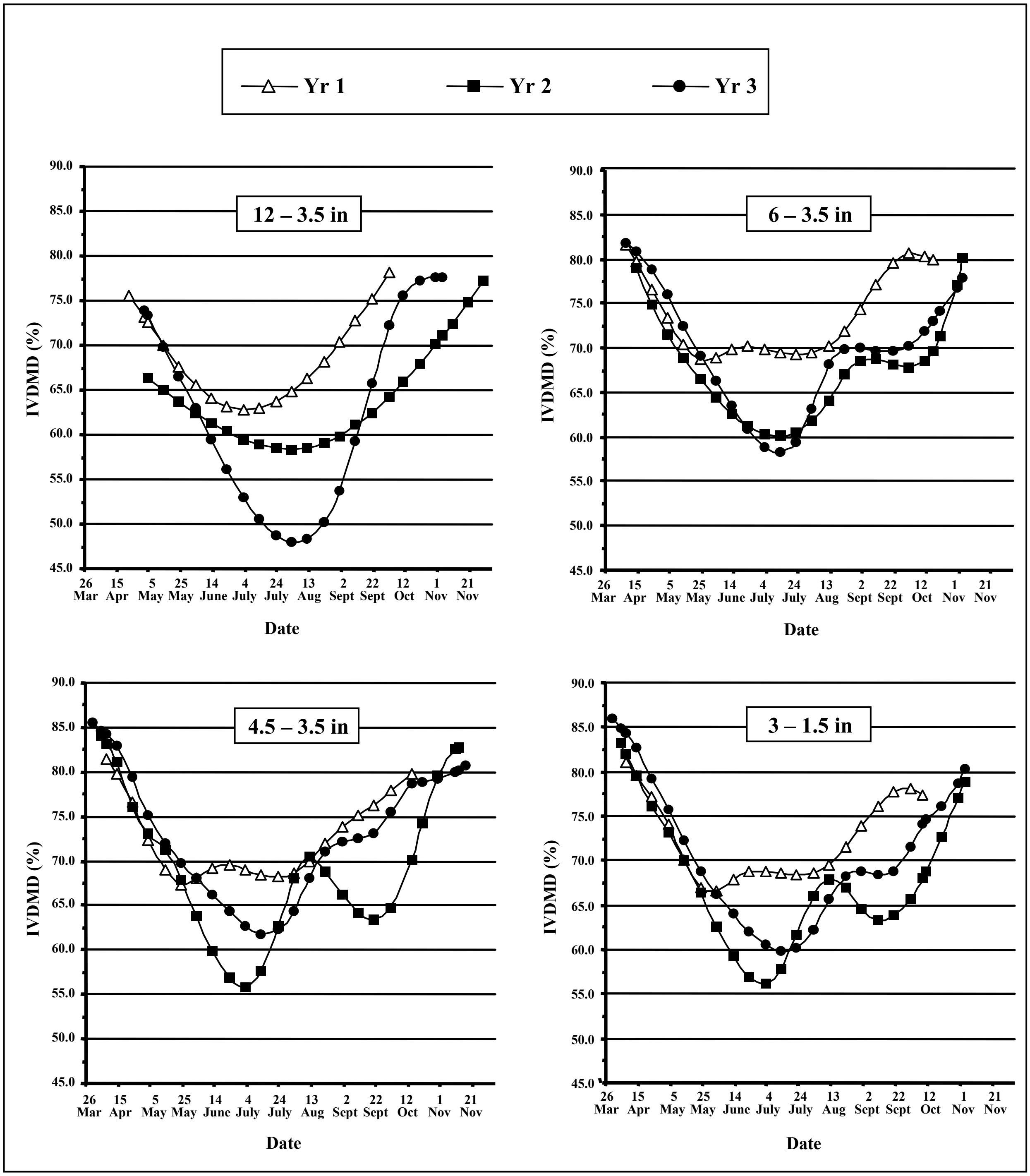
[a] Each value is the mean of three replicates.
[b] 60 pounds of N per acre were applied July 1 in addition to the 80 pounds per acre applied to all treatments on August 25.
[c] L = linear and Q = quadratic (J+N not included); NS = not significantly different.
[d] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) t-test.
[e] Each value is the mean of five treatments and three replicates (n = 15).
[f] Each value is the mean of five treatments, 3 years, and three replicates (n = 45).
[g] CV = coefficient of variation.



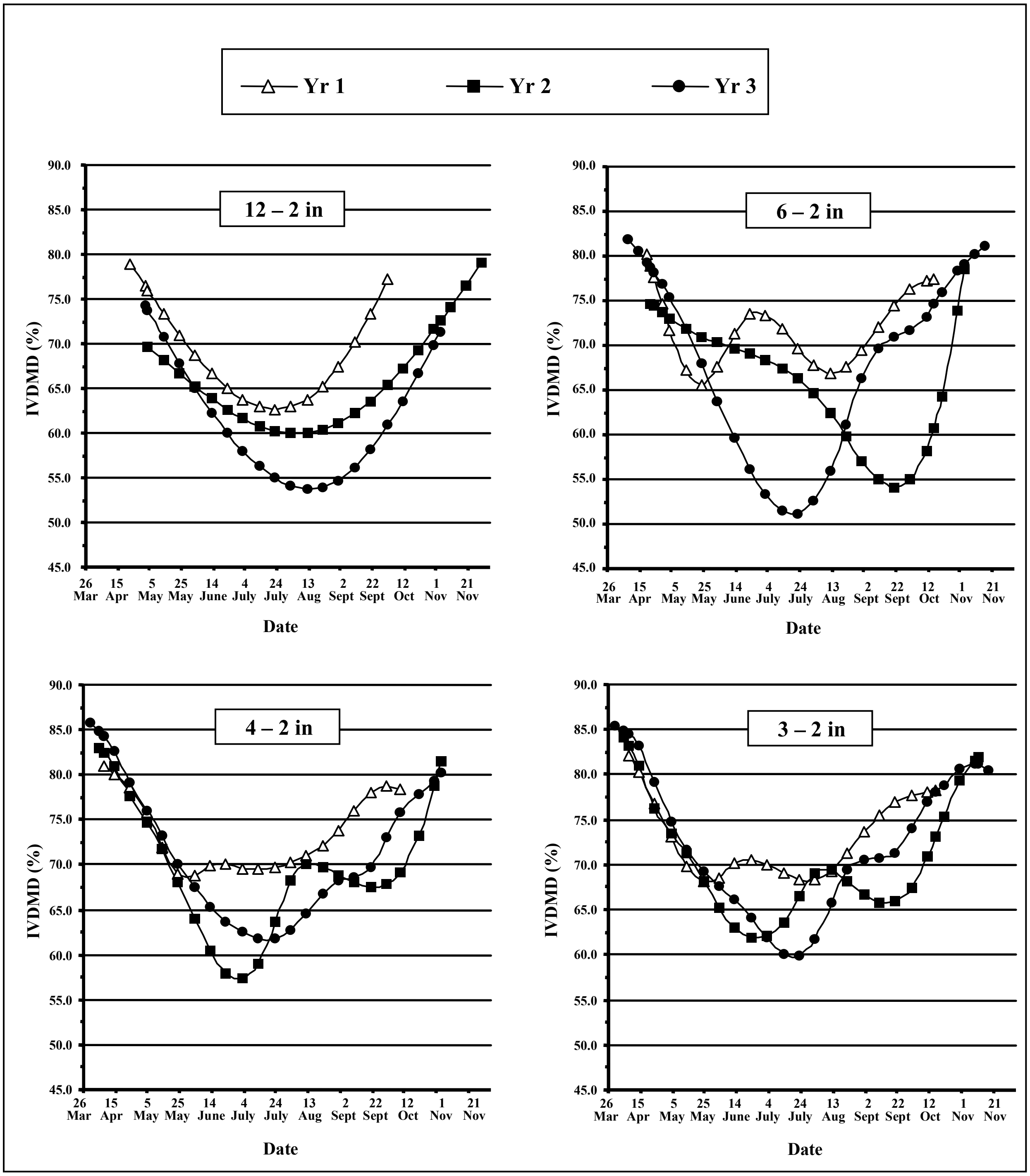
Appendix Figure 4.1. Daily growth rate changes of tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



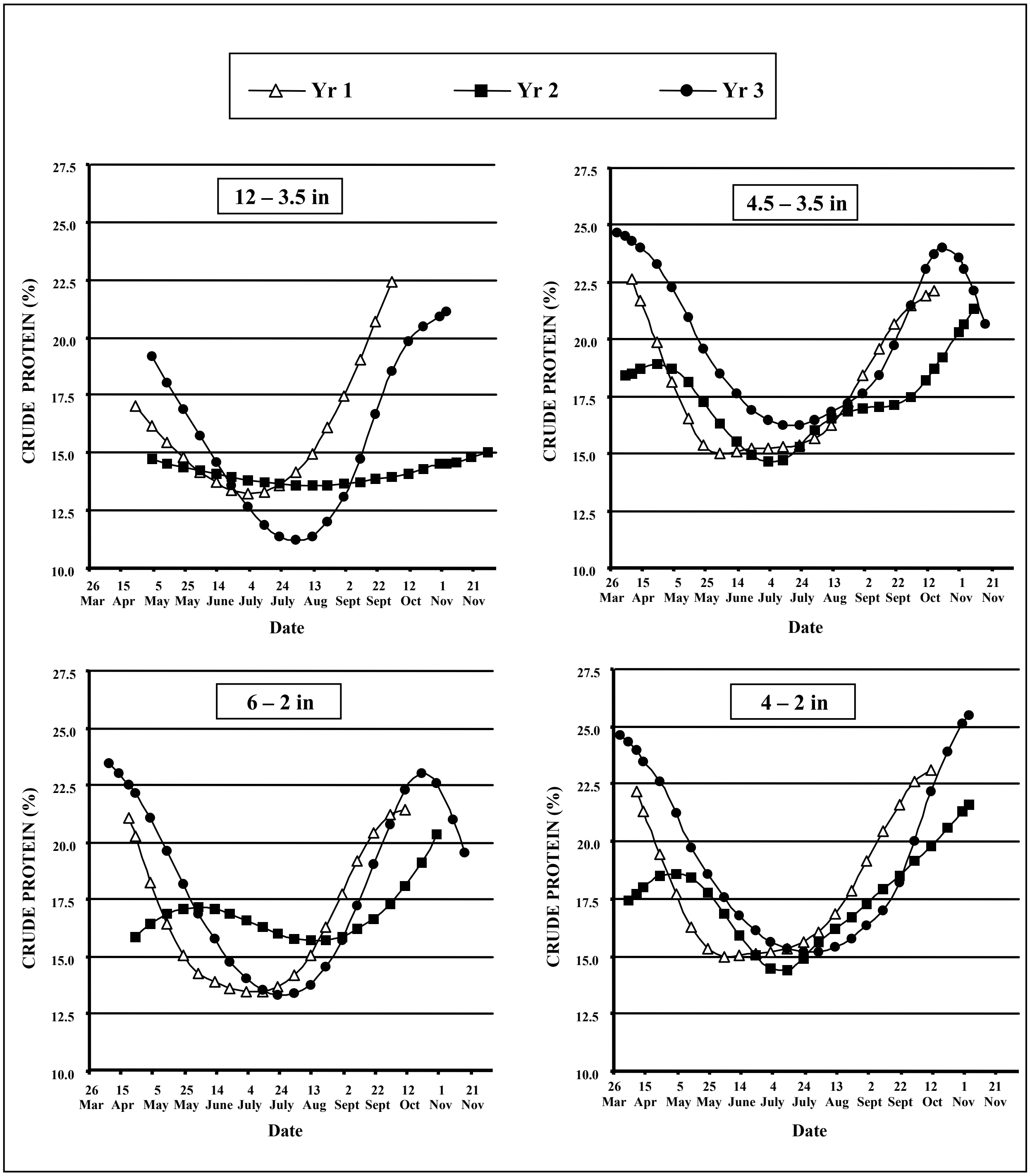
Appendix Figure 4.1 (continued). Daily growth rate changes of tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



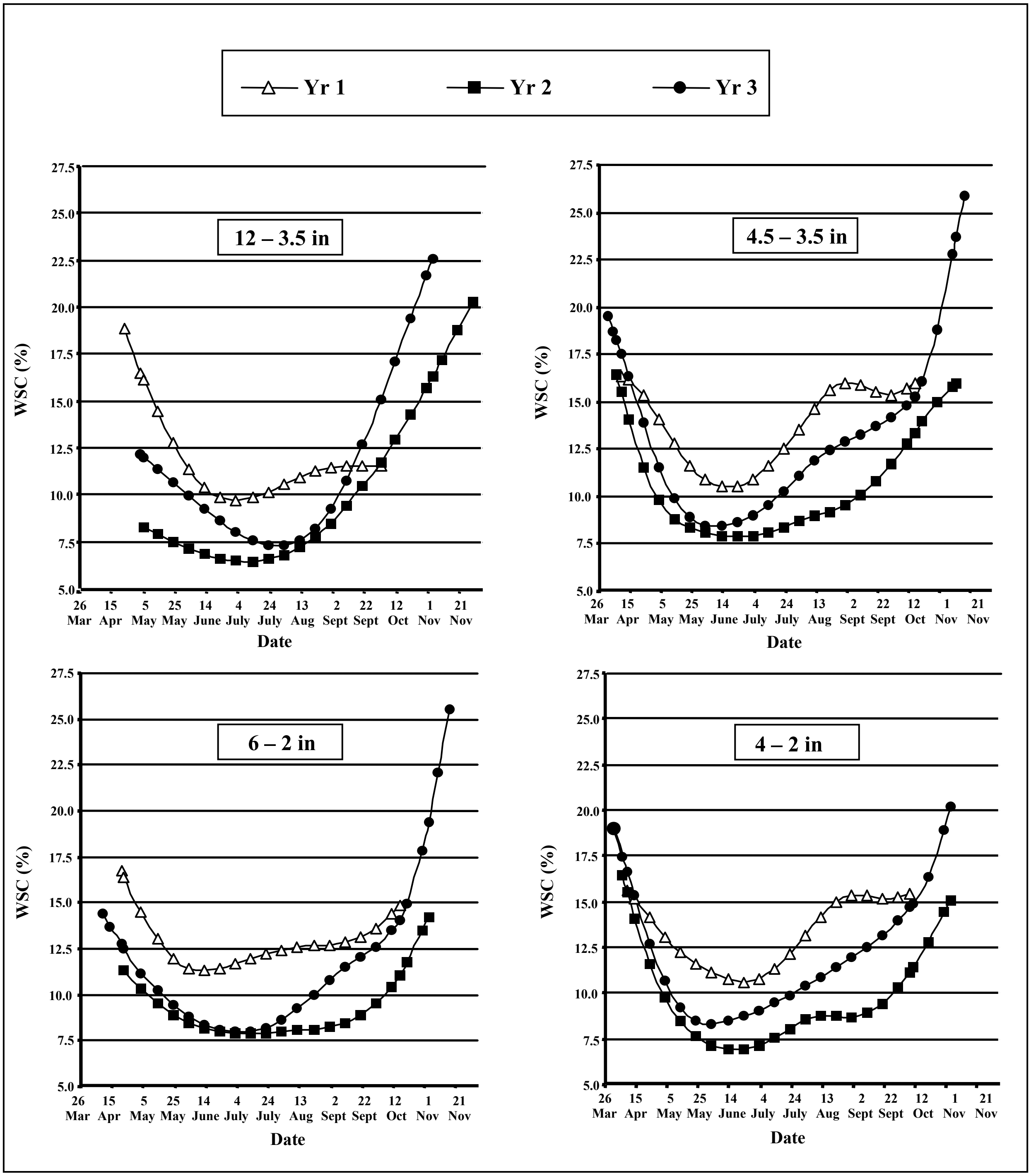
Appendix Figure 4.2. Changes in the in vitro dry matter disappearance (IVDMD) of tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



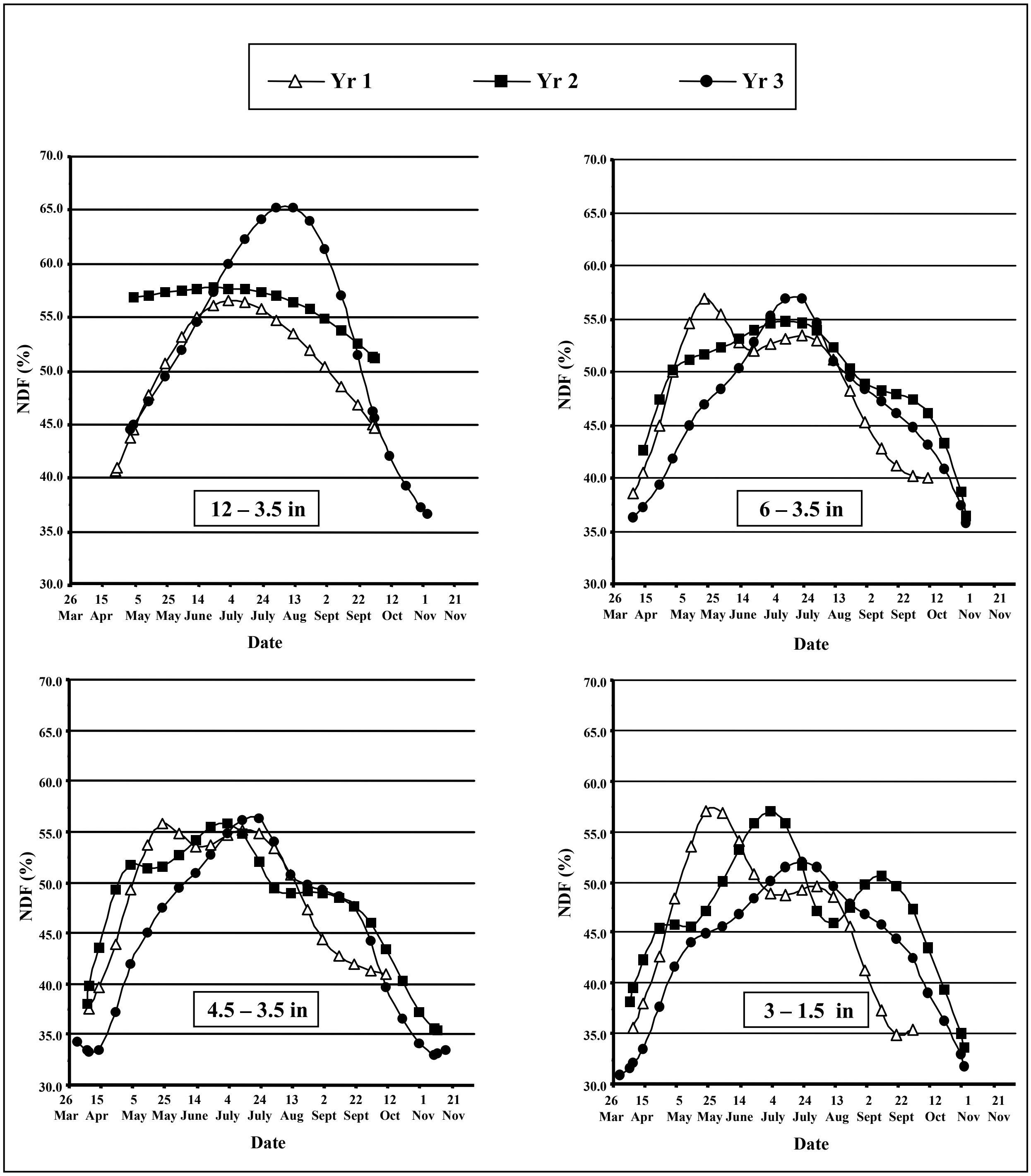
Appendix Figure 4.2 (continued). Changes in the in vitro dry matter disappearance (IVDMD) of tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



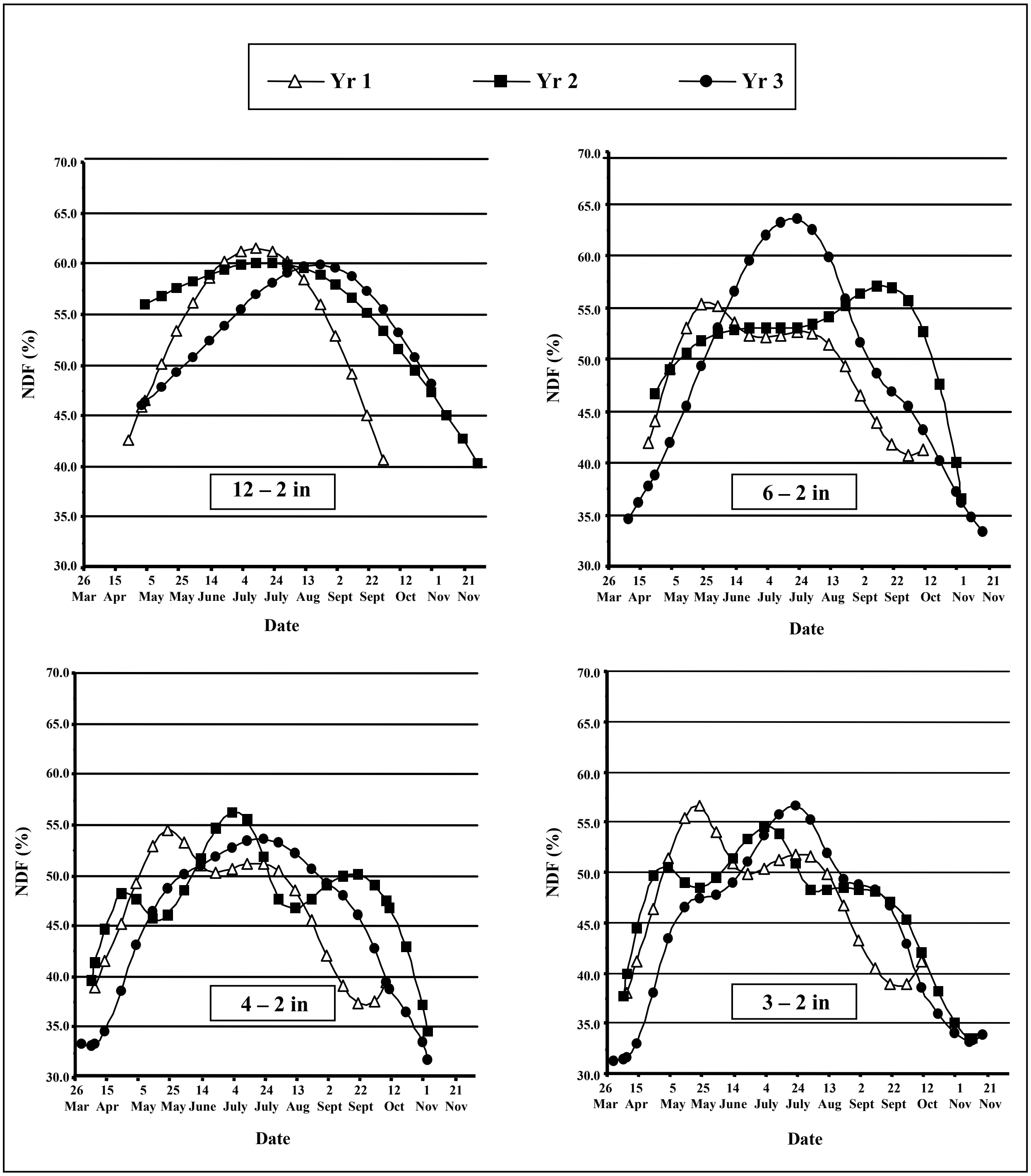
Appendix Figure 4.3. Crude protein changes in tall fescue throughout the growing season for each year within each of four selected defoliation intensities.



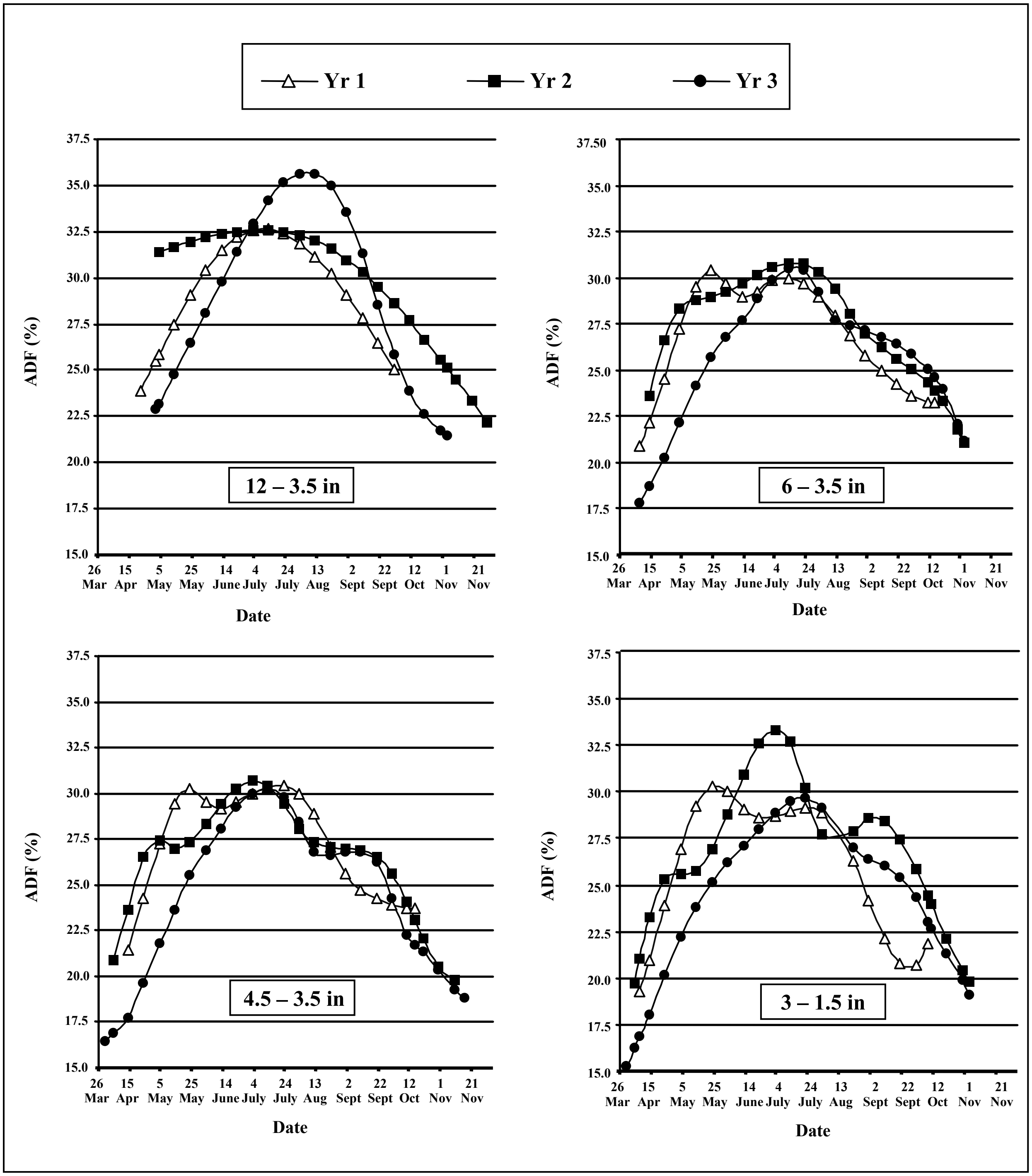
Appendix Figure 4.4. Water-soluble carbohydrate (WSC) changes in tall fescue throughout the growing season for each year within each of four selected defoliation intensities.



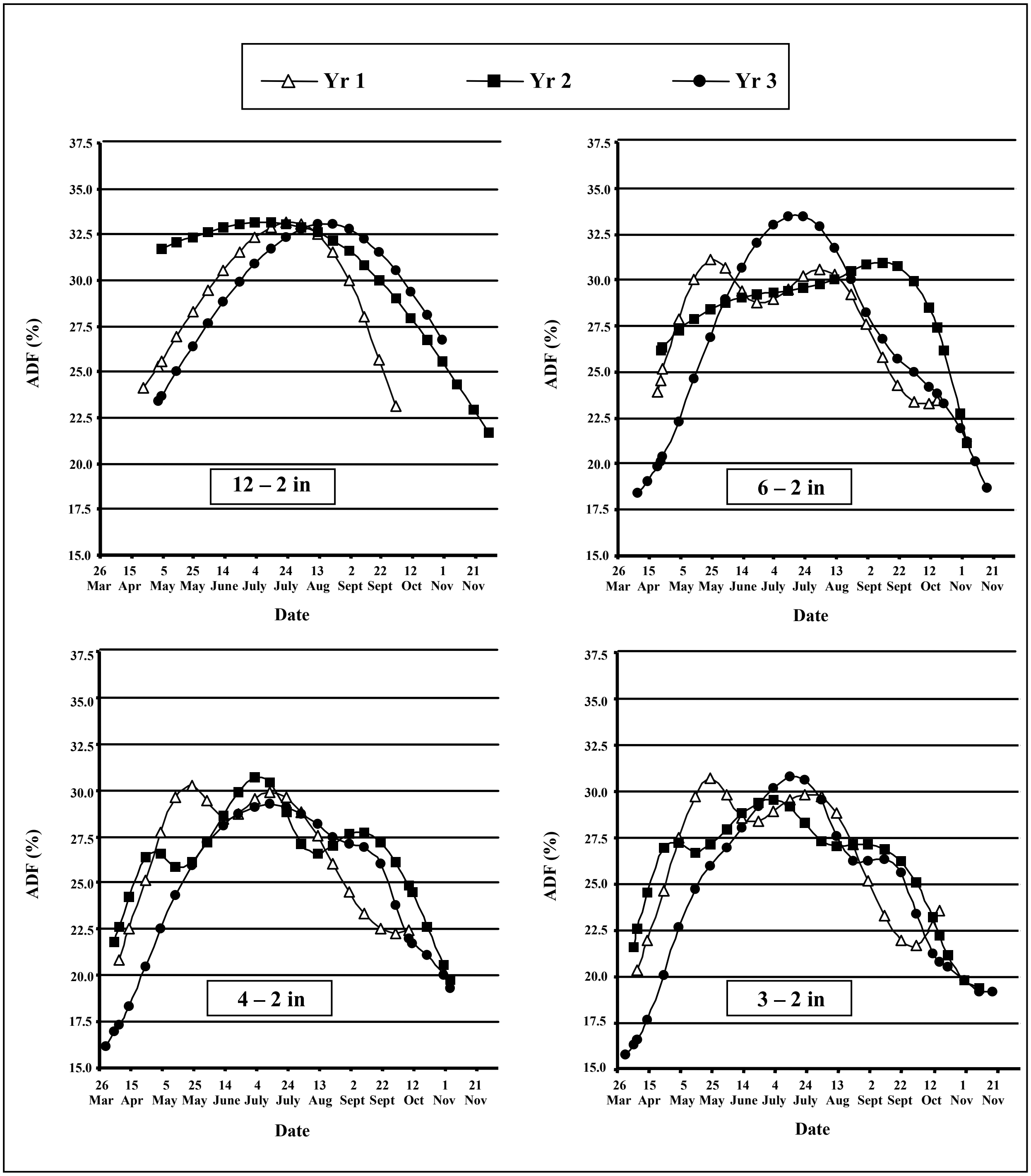
Appendix Figure 4.5. Neutral detergent fiber (NDF) changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



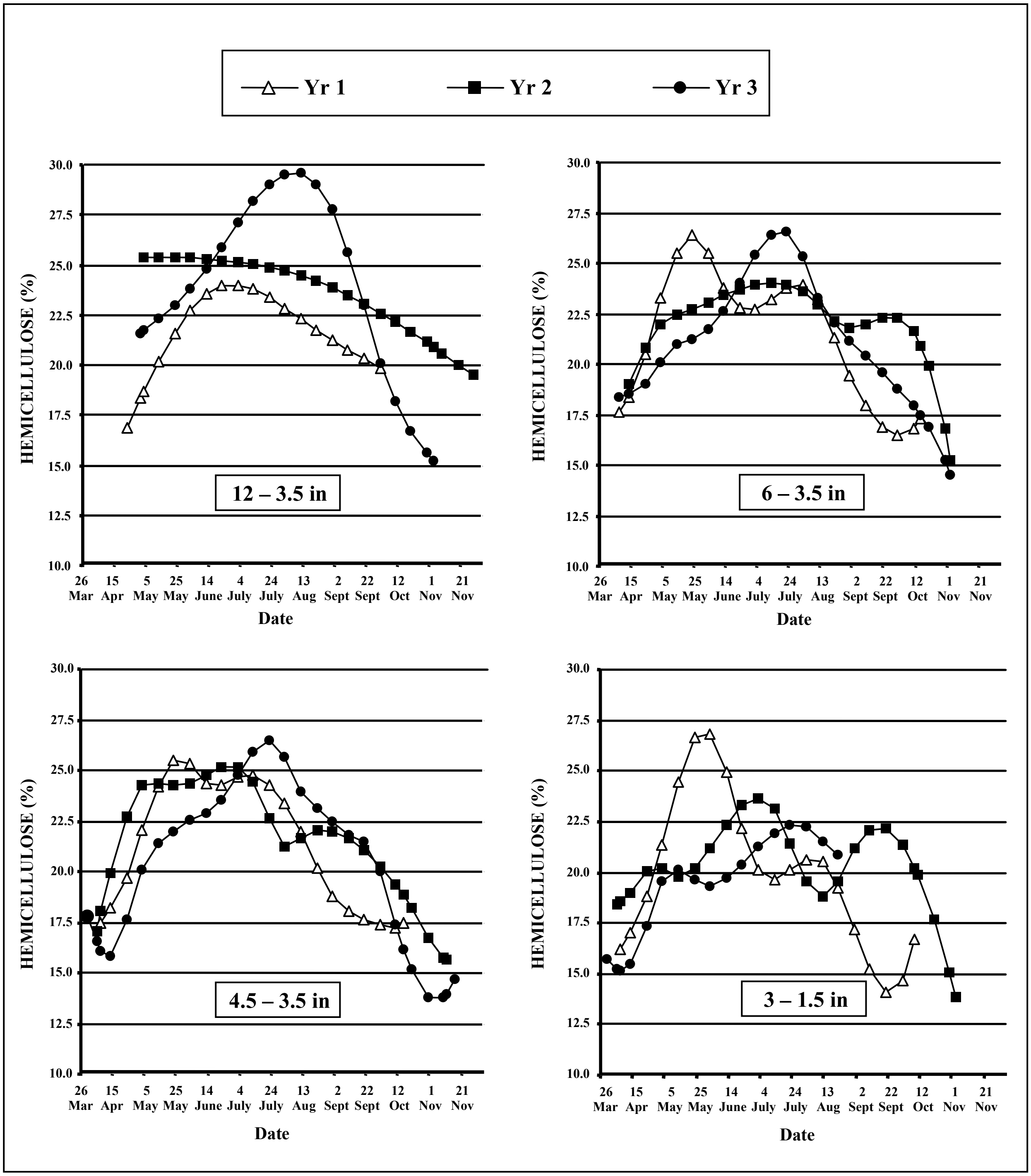
Appendix Figure 4.5 (continued). Neutral detergent fiber (NDF) changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



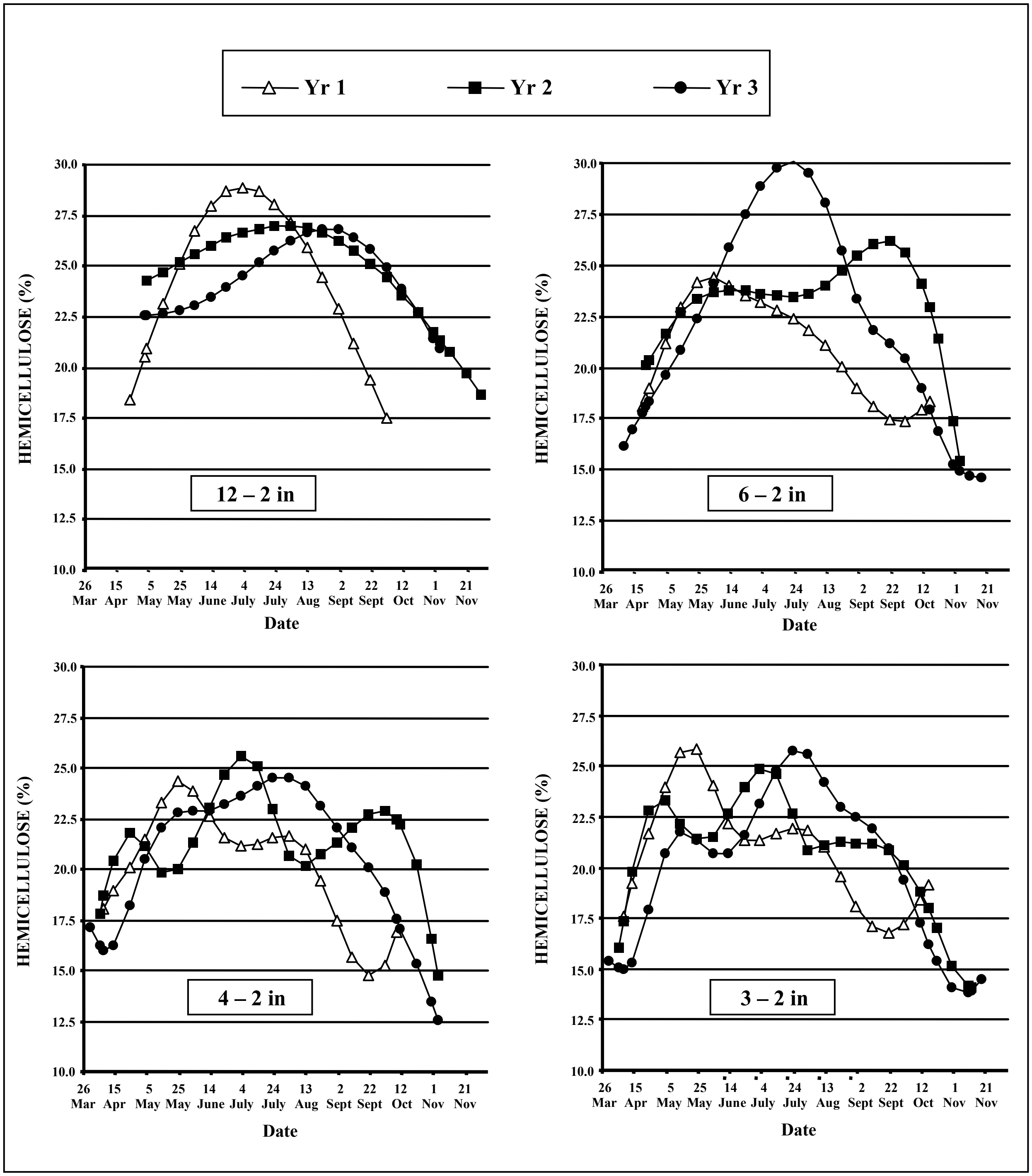
Appendix Figure 4.6. Acid detergent fiber (ADF) changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



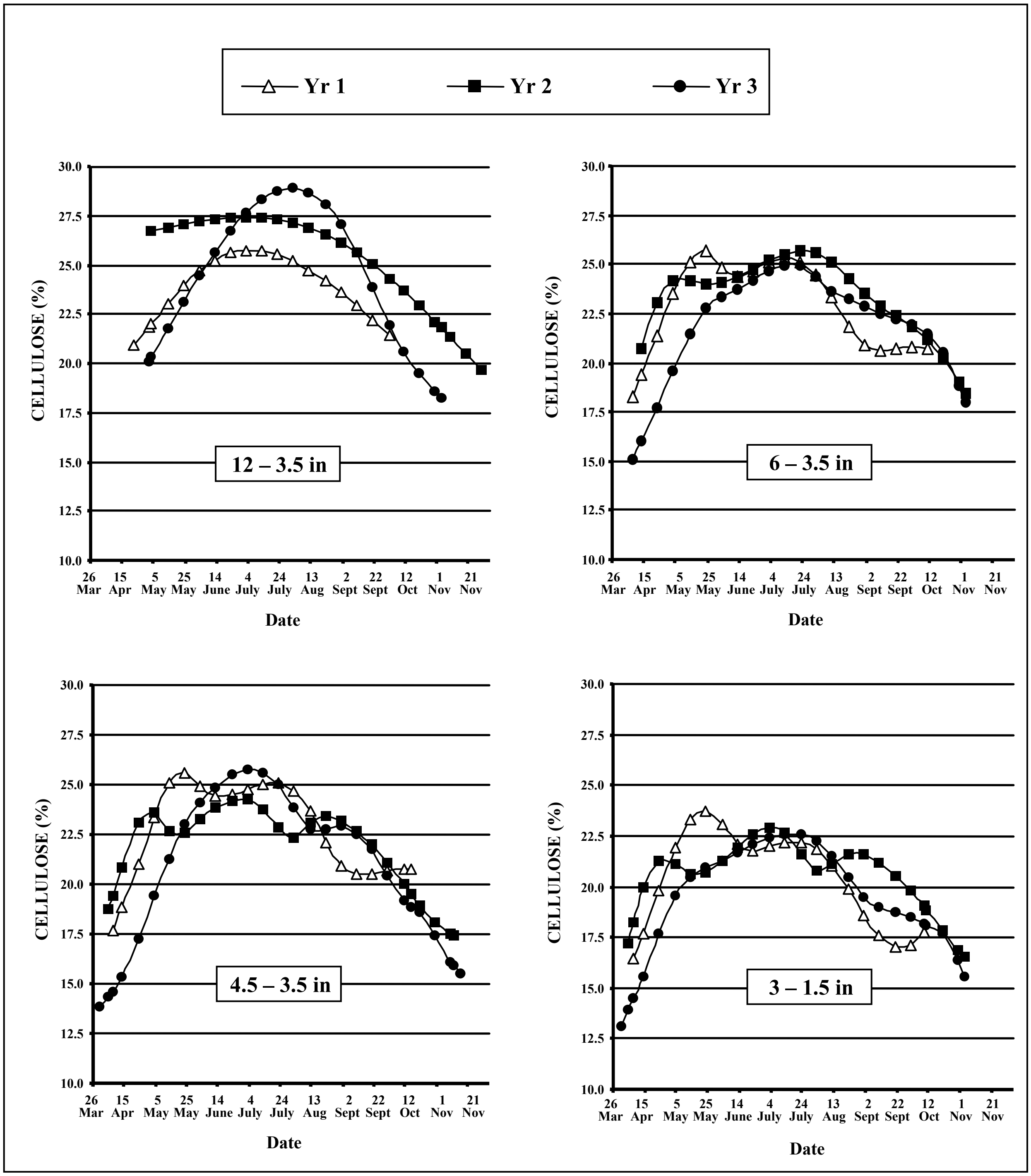
Appendix Figure 4.6 (continued). Acid detergent fiber (ADF) changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



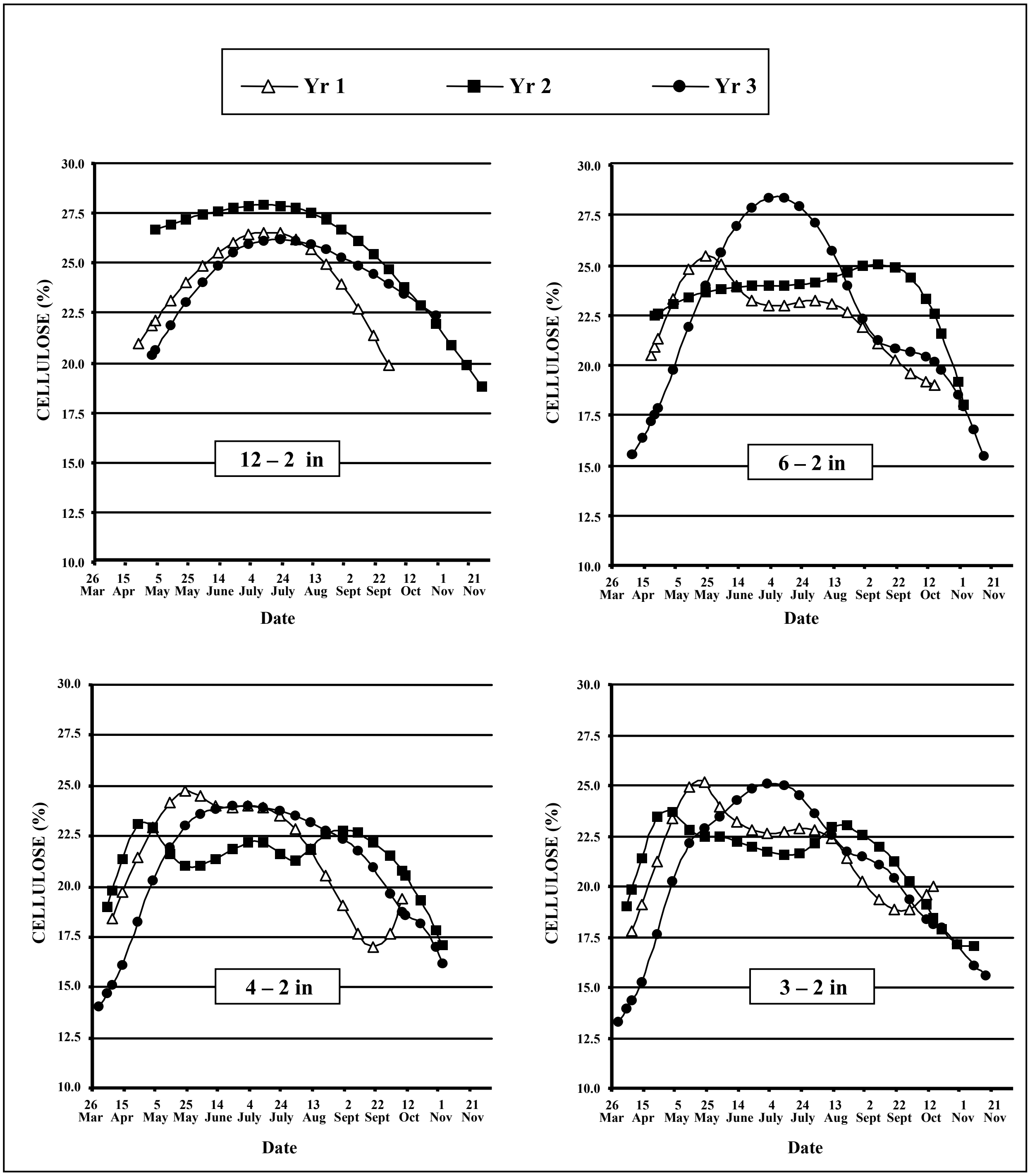
Appendix Figure 4.7. Hemicellulose changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



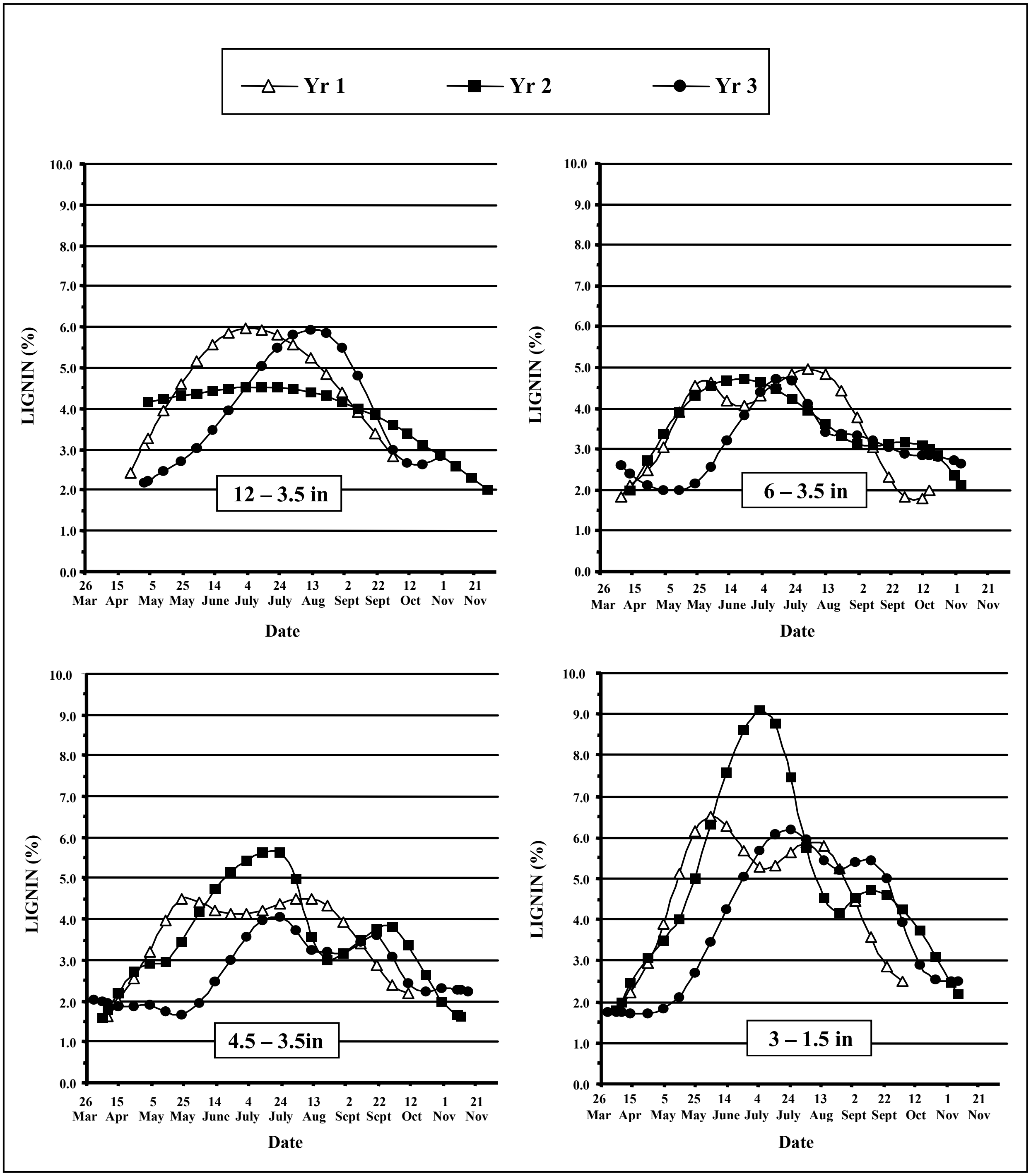
Appendix Figure 4.7 (continued). Hemicellulose changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



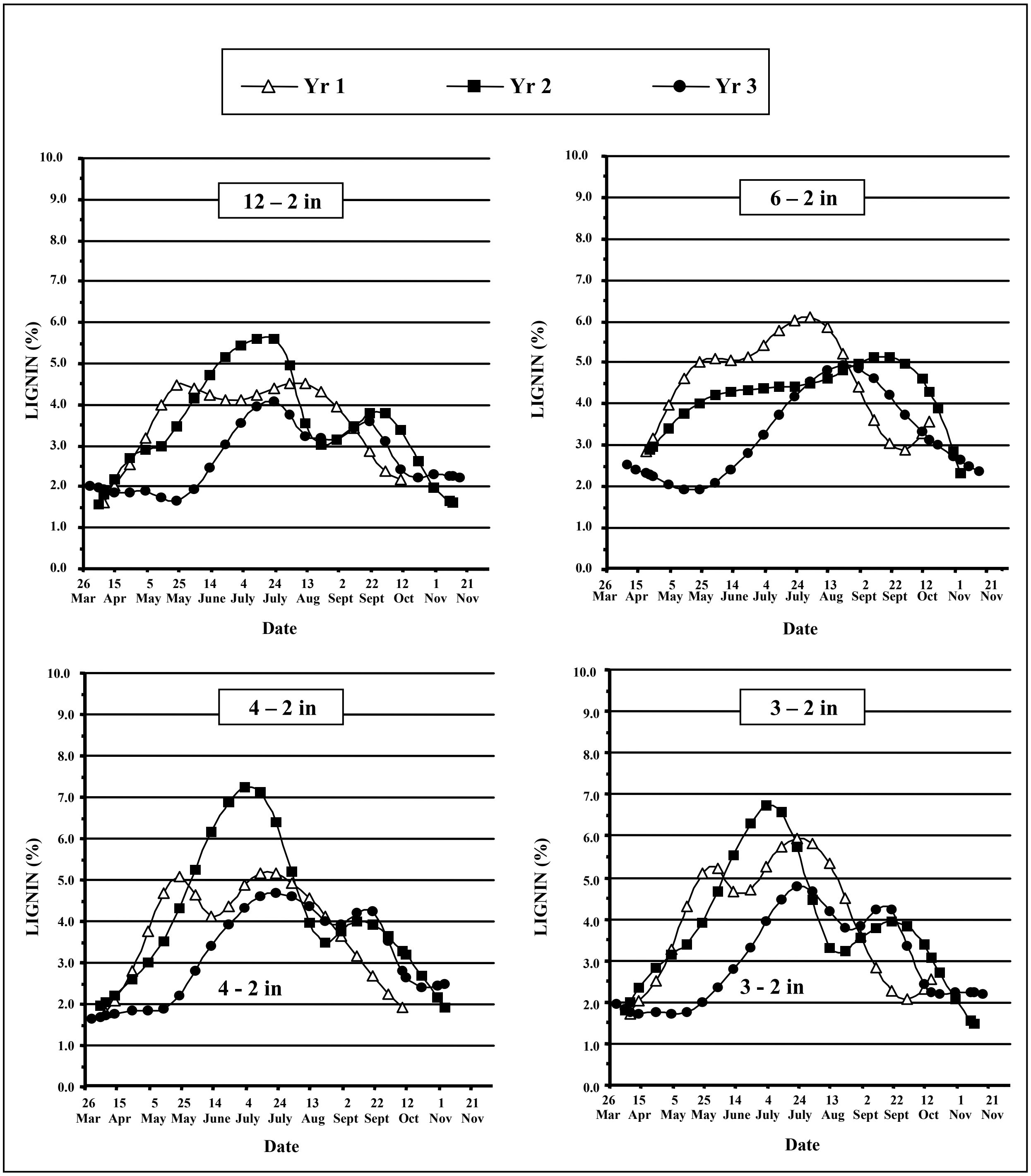
Appendix Figure 4.8. Cellulose changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



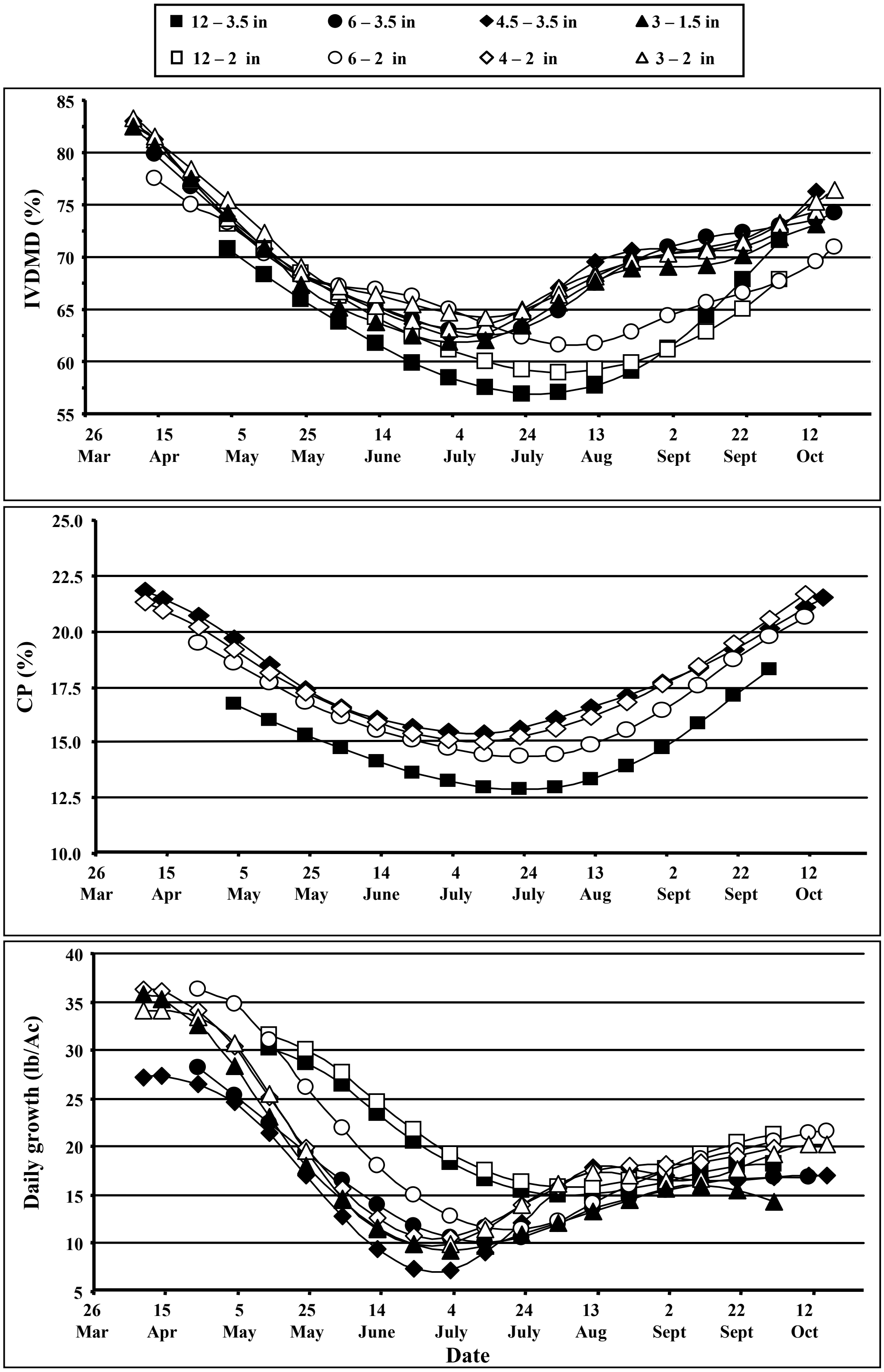
Appendix Figure 4.8 (continued). Cellulose changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



Appendix Figure 4.9. Lignin changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



Appendix Figure 4.9 (continued). Lignin changes in tall fescue throughout the growing season for each year within each of the eight defoliation intensities.



Appendix Figure 4.10. Three-year experimental mean changes in in vitro dry matter disappearance, crude protein concentrations, and daily growth rate of tall fescue throughout the growing season within each of the four or eight defoliation intensities.

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